Guide to Water Leakage Detection(WLD)

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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)(香港管線管理研究中心)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 Water Leakage Detection (WLD) (漏水探測). It states the whole process and specification of conducting WLD from planning to finishing stages and intended to be used by all personnel involved in the works.

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April, 2011

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1. INTRODUCTION

Water, especially fresh water, is an invaluable resource. However, due to aging and lack of maintenance of water pipes, vast amount of water leaks from the deteriorated pipes. This wastes our resource and also leads to potential incidents. Pipe burst is often news headlines and it may cause traffic congestion and inconvenience to the public. According to the Water Services Department, there are in total 2598 cases of water leaks in year 08/09. If such cases were prevented, it is estimated that 127 244 cubic meters can be saved per day. From 2000, the Government has been launching a large-scale pipe replacement and rehabilitation program to rejuvenate the water supply network.

As an active approach to reduce water loss, leakage detection and monitoring are essential. Traditional method, which relies on listening to water pipes, requires experienced personnel and is easily interrupted by background noise. New approaches and technologies are available to conduct a more effective detection. They can detect leaks in a more scientific way.

An accurate detection reduces loss of water and faulty excavation. Therefore, standardized requirements and sufficient information are needed for water leakage detection. Hong Kong Institute of Utility Specialists (HKIUS) (香港管綫專業學會) aimed at maintaining a healthy underground drainage system and safe working environment, prepared guidelines to provide a standardized process of conducting manhole internal condition survey in order to promote a good practice for the practitioners. Note that such standards are for reference only, any other standards or requirements are acceptable as long as they are stated in the contract or mutual agreement between the Contractor and the Engineer/ Client.

2. OBJECTIVE AND SCOPE

Water leakage detection is an assessment of the structural integrity of water mains, it pinpoints any leak points on the mains. The purpose of this guide is to provide recommendations on good practice of the methods and specification of water leakage detection to enhance the quality of the survey. Water leakage detection can be long-term monitoring and immediate pinpoint of any leak position. As the detection depends on detecting/listening to the sound waves caused by the vibration of the pipe, various factors may interrupt the accuracy of detection. This document provides a standardized process. It aims at providing guidelines for the practitioners to follow to improve the quality of the survey.

This guide provides information on the process and specification of conducting water leakage detection 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 water leakage detection, including contractors, utility companies, consultants, government departments and other parties concerned.

3. PRE-SURVEY PREPARATION

3.1 Planning for inspection

Before commencing a WLD inspection, the client (usually the asset owner) shall consider the desirability of providing the operator with all information available regarding the asset. More information available will enable the operator to present a better interpretation of the observations. Extra details such as map/ plan of the asset, size, material and class of the pipes, depth of manholes, etc, can then be permanently included in the operator's report enabling better comprehension and judgment by all those who might review the information.

On top, the client shall ensure the operator is aware of the operational requirements for the asset such as:

(1) Critical flow patterns that could affect the quality or safety of an inspection;
(2) Pumped discharges affecting the area to be inspected;
(3) Asset isolation / flow control procedures;
(4) Emergency procedures and a contact list in case of emergency;
(5) All relevant Occupational Health and Safety information.

3.2 Initial Site Inspection

Initial site inspection is essential to have a better understanding of the site situation. It also helps to determine which methods are suitable for the situation to get more accurate result.

(1) Identify the site boundary and double confirm with the client.
(2) Identify the major water consumers such as residents, restaurant and shop.
(3) Inspect any visible leakage near the survey area.
(4) Identify the prescribed section and predetermined points on site.
(5) Identify all valve pits and nearby manholes along the survey pipe.
(6) Use locators to confirm the alignment if the pipe route is unclear.

Past record can be acquired from asset owner for evaluation. Information such as Waste Detection Area (WDA) drawing, the result of Minimum Night Flow Test (MNFT), the leakage report and other significant data (i.e. major consumer in the area, the condition of cut-line valve and any special valve such as left hand turn valve) are very useful.

All the pipe section, boundary valves, sub-boundary valves and selected section valves of WDA drawing was highlighted. The operating sequence of section valves was planned for step test.

3.3 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 Occupational Safety and Health Ordinance (Cap. 509) and the Factories and

Industrial Undertakings Ordinance (Cap. 59) specify several requirements for personnel involved in works, some of the requirements are stated in relevant ordinances or regulations such as working in 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 risk of injuring the public. In case 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. Such regulations can be referred to Cap. 28, the Land (Miscellaneous Provisions) Ordinance.

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

3.4 Personnel Requirement

In order to maintain the Utility Profession's requirements for the consistency, reliability and accuracy of reports, CCTV inspection 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.

In addition, a minimum of 3 years post training experience will be necessary for a person to become competent. Besides, qualified personnel are required to attend refreshment course in every 3 years to refresh and enhance their knowledge.

All works carried out within sewers, manholes or other confined spaces 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 precautions 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

3.5 Prevention of damage to pipes and other utilities

The operators shall aware that there is an extensive network of utility underneath the pavements. Breaks of pipes are usually caused by direct or indirect road opening works. It is essential that the operators shall avoid causing damage to the pipes during execution.

Accident like the manhole cover falling back into the manhole when uplifting it may destroy other pipes and utilities passing through the manhole. Dropping of heavy materials may also cause damage to utilities. Therefore, the site supervisor shall perform close supervision to the workers. The supervisor shall remind the workers occasionally to be careful and the importance of preventing damage to the water pipe and other underground utilities and the consequences of damage.

Circulate the layout plans with relevant details to Water Supplies Department (WSD) to request indication of the alignment of existing water mains so that the operators can have more comprehensive information about the pipes nearby and hence lower the risk of destroying other pipes. If excavation work is needed, operators shall use hand-digging method instead of using heavy mechanical plants near the water pipes. More information can be found in the guideline “How to Prevent Damage to Water Mains?” proposed by WSD.

As there may be explosive gases inside the chamber or pipe, explosion proof survey equipment shall be used to prevent the drain from being damaged by unexpected explosions. Use of fire and smoking near manholes must be strictly forbidden to avoid any fire-induced explosions and accidents.

4. LEAK DETECTION METHODS AND PROCEDURES

4.1 Detection of leak positions

Detection methods are very mature for water mains with less than 300mm in diameter and metal in material at the moment.

When water distribution system is operated under pressure, any leak in the system generates a distinctive acoustic signal. The most commonly used technique for the identification of these signals is the Leak Noise Correlator, developed in the early 1970's by WRc. And the Acoustic Methods can locate leaks accurately without interrupting the water supply system.

In general, Pipe and Cable Locator (PCL) Survey(An Alternating Current will be induced into metallic pipes utilizing a signal transmitter and the receiver above ground will then locate the signal. Acquired data will be marked on site by spray paint and mapped / surveyed by the land surveyor only when further instructions are received from the client with additional cost. A digital map will be submitted to client as one of the submittals, which can be easily updated as and when required.) will be undertaken to locate and map the underground-pressurized water mains by utilizing the Electromagnetic Induction Method before the leakage detection.

Detailed Procedures are explained as follows:

Step I: Visual inspection

Visual inspection shall be carried out in the initial stage to find out if there are obvious clues of leakage like water spots and seepage. Observing the physical characteristics of the leaks and testing them may identify the source of leakage.

1. Physical characteristics of leakage offer hints to the type of water sources.
2. Sewage pipe – turbid, smelly, continuous, white grey slime
3. Stormwater drain – clear, leaking during and after rainy days
4. Salt water pipe – clear, continuous, leaking confined to isolated spots, high chloride content
5. Portable water pipe – clear, continuous, leakage confined to isolated spots

Physical characteristics by no means give comprehensive data to the source of leakages, water sampling and confirmation test shall be carried out.

Verification tests include laboratory chemical tests as well as physical tests on site. For fresh water supply system, a diethyl paraphenylene diamine (DPD) tablet can be used. For salt water supply system, chloride test (Merck) strip can be used. A few drops of 10% barium chloride solution can also test the chloride content of the salt water. For sewage system, smoke testing or fluorescent non-toxic dye test can be performed. It shall be noted that the water samples collected shall be kept from contamination to retain an accurate result. Further information on water sampling and testing can be found in the Code of Practice on Monitoring and Maintenance of Water-carrying Services Affecting Slopes (Works Branch, 2006).

Visual inspection and seepage investigation gives clues to the type of water sources, to locate the exact location of leakages, the following methods can be employed depending on the types of conduits.

Water leaks in the water main or sewer are used to detecting by acoustic technology in which general terms uses measuring devices to detect vibrations and/or sound waves.

Step II: Initial Minimum Night Flow Test (MNFT)

Possible leaking Waste Detection Areas (WDAs) can be identified by comparing the Flow Test Data against control/historical data, such data was collected by WSD Waste Detection Unit.

To establish a set of control data for minimum night flow to verify the volume of water saved after leak detection and repairing works.

General Procedures to be adopted for MNFT are as follows:

(1) All valves and counters were checked to ensure their locations against records such as Waste Detection Area Drawings.

(2) All boundary valves were shut off with one exception, the main valve that is to be shut off after installation of waste detection meter.

(3) The cover of meter chamber was removed and the waste detection meter (WDM) was installed with a pressure recorder with record printer on top of the meter at the meter position.

(4) The readings of the WDM were recorded before commencement of test.

(5) Two by-pass valves were opened.

(6) The main valve was shut off.

(7) Let the water flowing via the WDM for at least 15 minutes.

Step III: Pressure drop test
Shut off the inlet valve at the meter position and note for the pressure drop in the WDM. The pressure in the pressure recorder drops downs to around 12psi and then drops gradually and continuously. This means all boundary valves in this site are closed. The pressure drop test is acceptable. The pressure may or may not drop to zero, which is depending on the meter position.

Step IV: Flow Test
The inlet was re-opened at the meter position after finishing the pressure drop test with acceptable result, and the flow test started.

Staff was assigned at the meter position to look after the WDM and notice for any major change while testing. Visual and Sounding Inspection were conducted for suspected leaks. Suspected leaks were marked on site and reported to WSD. Leak Noise Correlator (LNC) survey and further investigation were conducted to locate suspected leak and reported to WSD for repair.

Flow and pressure were recorded once all boundary valves were shut off and WDM was installed.

Step V: Step Testing
Isolation of leakage to individual mains or street resulting in a reduction in the amount of sounding required.

Quantification of the leakage within those steps thus reducing the likelihood of leakage being missed through routine sounding

The method of closing valves within the district is aimed to successively reduce the size of the district supplied by the meter. The resultant reduction in flow rate following the closure of a particular valve indicates the total leakage plus the legitimate night consumption in that section of the distribution system. If the resultant reduction in flow is greater than the reduction anticipated, taking into account the number and types of consumers in the section isolated, then it is indicative of a leak. There are several ways in which the step test can be undertaken but in all cases the district is set up for taking a night line and all circulating valves are closed in order to remove all loops within the district to produce a tree like main layout.

General procedure is summarized as follows:

(1) Pressure drop test was conducted to confirm all the boundary valves were shut off properly. If not, find out the reason and fix it.

(2) The inlet was opened at the meter position and let the flow run for 30 to 60 minutes.

(3) All sub-boundary valves were shut off to isolate concerned areas to smaller portions.

(4) Section valves were shut off starting from the outermost point from the meter position and then towards the meter position.

(5) The section valves were closed step-by-step in a 10-minutes interval and the time for closing was recorded.

(6) Changes in flow and pressure in the WDM were noticed by the position staff and to inform the Team Leader.

(7) The test will be ceased in case flow has dropped to zero after closing of section valves or until the nearest valve, i.e. the outlet of the meter position is closed.

4.2 Leak Noise Correlation Survey

Verification of pipe alignment

Before the LNC Survey, the Utility Specialist shall locate and identify all underground services within the sites to be investigated. Utility installations on the ground surface like manholes and fire hydrants give hints to the alignment and location of the underground utilities. Though excavation shows a clear picture of the underground utilities, it is inefficient, more dangerous and may cause damages to the utilities easily. Utility mapping/survey can be carried out to identify and locate underground services without excavation.

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

Electromagnetic Utility Detection

The method of electromagnetic 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 in 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 and applies 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 may 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 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.

Leak Noise Correlation
LNC Survey is one of the most common methods to detect leakage. Other methods shall be used unless LNC Survey is not suitable or the result yielded is unsatisfied. Leak Noise Correlator is an electronic device that would analysis the leak noise and the location of leakage can be found. Manual listening of leak noise is exempted in this method.

The typical set up for an effective leakage location operation involves the central unit (Correlator), the radio transmitters or the cable drums or a combination of radio transmitter, cable drums and sensors (accelerometers or hydrophones or a combination of accelerometer and hydrophone). The microphones are attached to contact points (such as hydrants, meters and valves) along the water main to be surveyed and are connected to transmitters for collecting the leak noise. The Correlator crosses correlates the leak noise reaching two microphones to calculate the suspected leak position. The Correlator is capable of filtering the background noise so that a more accurate result can be obtained. The equipment shall operate at digital basis and have the following capabilities:

It shall be able to cover a survey distance of at least 1000 meters with the capability to measure different combination of pipe materials and different pipe diameters.

The accuracy of measurement shall be within ±5% of the survey length or 5 meters.

Maximum radio transmission shall reach 500 to 1000 meters.

Frequency interval for both cable and radio is between 5 and 4000 Hz.

It shall have data storage and print out functions to record the survey inputs and results.

The Utility Specialist shall follow the instructions of the equipment supplier to carry out the survey. Basically, the procedures are as follows. The sensors are placed at the extremes of the section of pipe under analysis to pick up the leak noise. They can be fittings or any convenient contact point so that the sensors can be attached firmly. Accelerometers are attached to the valve spindles or hand wheels of valves installed along the section of pipe under analysis.

Any leak noise the microphones detected would be transferred to the transmitter. The leak noise will be transmitted back to the central unit, either by radio signals transmitted by the transmitters or by direct connection to the sockets in the LNC by cables.

The operator shall apply different frequencies and filters to obtain the best accuracy. Information of the pipe under investigation shall be entered correctly into the Correlator to reflect the field measurement as provided in the Record Drawings.

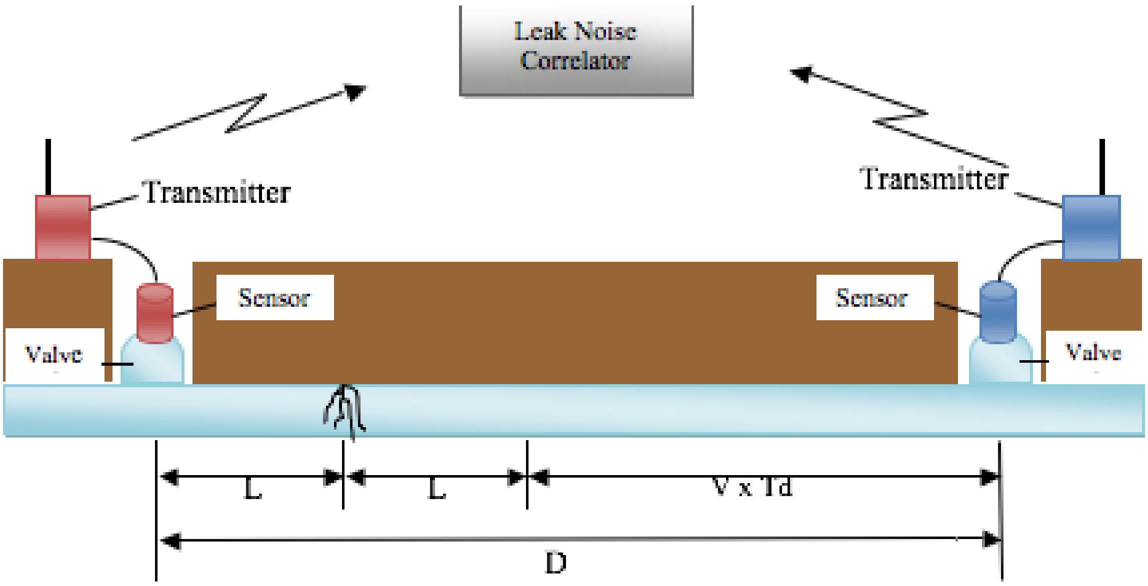

Fig. 4.1.1.2 Sample set up of LNC Survey.

The formula for calculating the leak point is $L = \frac{D-(V \times Td)}{2}$

Where:

L=leak position

D= distance between sensors

V= velocity of sound for pipe under consideration

Td= time delay (transit time difference)

A Correlator works by detecting the sound from the leak when it arrives at the two sensor points on the pipe, either side of the suspected leak position. The sound firstly arrives at the sensor which is closest to the leak; then there is a "time delay" (Td) before the sound arrives at the furthest sensor. This time delay, combined with the knowledge of the distance (D) between the sensors and the velocity (V) of the sound in the pipe, enables the Correlator to calculate the exact leak position (L). Graph of frequency measurement is generated and the suspected leak position is indicated automatically.

The leak position is usually the peak of the graph. If the peak is distinct, the position is most probably the leak point. If the graph is fluctuating and the peak is not obvious, there is probably no leak or the result may be interfered by other factors.

Hydrogen gas detection

This method involves the use of light gases and a gas detector. Leakage can be traced by detecting the light gas rises up to the surface from the leak point. The low viscosity and low density of the hydrogen gas allow it to penetrate the ducts and the ground materials easily and then rise to the surface. The tracer gas is a standard ready-mixed industrial gas mixture containing 5% hydrogen and 95% nitrogen. The gas mixture is safe to use, as the hydrogen is sufficiently diluted, and is inexpensive.

The tracer gas is first injected into the pipe. The gas will diffuse in the pipe, gradually penetrates the pipe material and rises to the ground surface. The rate of penetration of the gas varies depending on the pipe materials. The operator shall allow sufficient time period for the process. The higher the density of the ground, the longer the waiting time will be.

Type of Ground	Approximate Waiting Time
Dry Sand	15 Mins
Dry Soil / Wet Sand	1 Hour
Wet Soil / Dry Clay	4 Hours
Wet Clay	12 Hours
Asphalt 5 cm (2”)	Add ½ Hour
Asphalt 20 cm (8”)	Add > 12 Hour

Table 4.1.2.1 Waiting Time for Gas to Penetrate Different Materials.

The gas rises from the alignment can be detected by a gas detector, which shows the concentration of the gas detected. The suspected leak point is where a higher concentration of gas presents.

Temporary noise logging

Noise Loggers record the acoustic noise generated by the leaking pipes. Loggers can be deployed to any suitable location to trace for suspected leaks. Generally, logging period is set to 2 hours interval typically from 02:00am to 04:00am to avoid any unwanted noise generated from user consumptions. Logger can be programmed to work in the mentioned period in office by software working on PC or laptop computer.

Data stored in the logger will be downloaded for analysis via the same software. 2-D or 3-D views can be generated with those data to identify any suspected leaks. A sharp, continuous peak indicates the suspected leak as noise from leaking water is usually of narrow banded and continuous.

Other noise recorded, widely spread or stop quickly, shall be classified as noise generated by suddenly increased traffic load, pumping noise, temporary water consumption etc. Suspected leaks will be followed up by pinpointing activities such as MLD Survey.

Acoustic detection equipment

The leak is pinpointed by using acoustic detection equipment: A Ground microphone and listening stick. On solid surfaces the ambient noise protected microphone by suppressing noise caused by wind, rain as well as loud traffic. Special attention has to be paid to the optimum setting of receiver at narrow-band reception and the pre-selected setting has to be retained during the whole location. The microphone is set down on pre-marked route of the pipeline at an interval and the meter indication as well as noise in the headphones is compared. The point of maximum intensity is the potential leak position.

Mechanic Leak Detector

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.

Geophone

A geophone is similar to doctor's stethoscope that amplifies and transfers the leak noise to the operator's ear directly through the sensing heads.

Direct contact of the sensing head against the contact points shall be made and the operator shall listen for the leak sounds. Contact points can be pipes, valves, fittings, ground / road surface. Placing the sensing heads on the ground firmly against the surface, move the sensing heads along the top of water main until the sound is the same intensity in both sensing heads reaching both ears at the same time and the operator is exactly above the leak location.

Listening stick
Listening stick is the oldest but extremely effective method for leak detection. It consists of a probe bar, a diaphragm and an ear piece. The resonance chamber amplifies the leak noise so that the leak point can be located by identifying the highest leak frequency.

The probe bar shall be placed firmly on contact points of pipes to listen for leak sounds. Trace the leak position by listening against the ground surface. Move along the top of the water main under survey at two meters interval, listen carefully, the location with the highest leak frequency is the leak point.

Contact points of water mains such as hydrants, valves and meters are conductors. It is possible to have electric shock or even electrocution when conducting the survey. Therefore, the equipment shall be properly insulated to ensure a safe survey.

Besides mechanic listening stick, electronic listening stick is introduced for a more accurate result. However, some of the operator prefers the mechanical one as there is no crackle of electronic noise in the background.

Electronic Leak Detector
Electronic Leak Detector consists of a ground microphone, an amplifier and a frequency filter. The sound of leak is amplified and transmitted to headphone, loudspeaker or indicating meter electronically. Unwanted noise can be removed by electronic frequency filters. A LCD indicator shall be included for digital data readout or leak noise level display.

Use contact microphone to listen for leak sounds at meters, hydrants, valves and other points of direct contact. Place the sensing heads on the ground firmly against the surface. Then, take readings along the top of water main at two meters interval. Listen to the sound, and adjust the filter for the highest response to the leak frequency to locate the leaks.

4.3 The Sahara Inspection System

When detecting signals generated by leaks, the strength of signal will dissipate rapidly within large diameter water mains and the following methods are designed to overcome the difficulties for better performance.

The Sahara inspection technology is a non-destructive, in-line, condition assessment tool that can detect leaks in large diameter (12” (300mm) or greater) water transmission mains of all materials without interruption of service. Once a leak has been detected, the technology is used to pinpoint its location and size of the leak, all in real time during the inspection.

The equipment inserted into the main is made of materials that are suitable to use in contract with drinking water and all equipment is sterilized before insertion into live pipeline.

The basic inspection process of Sahara (produced by PPIC) is summarized as follow:

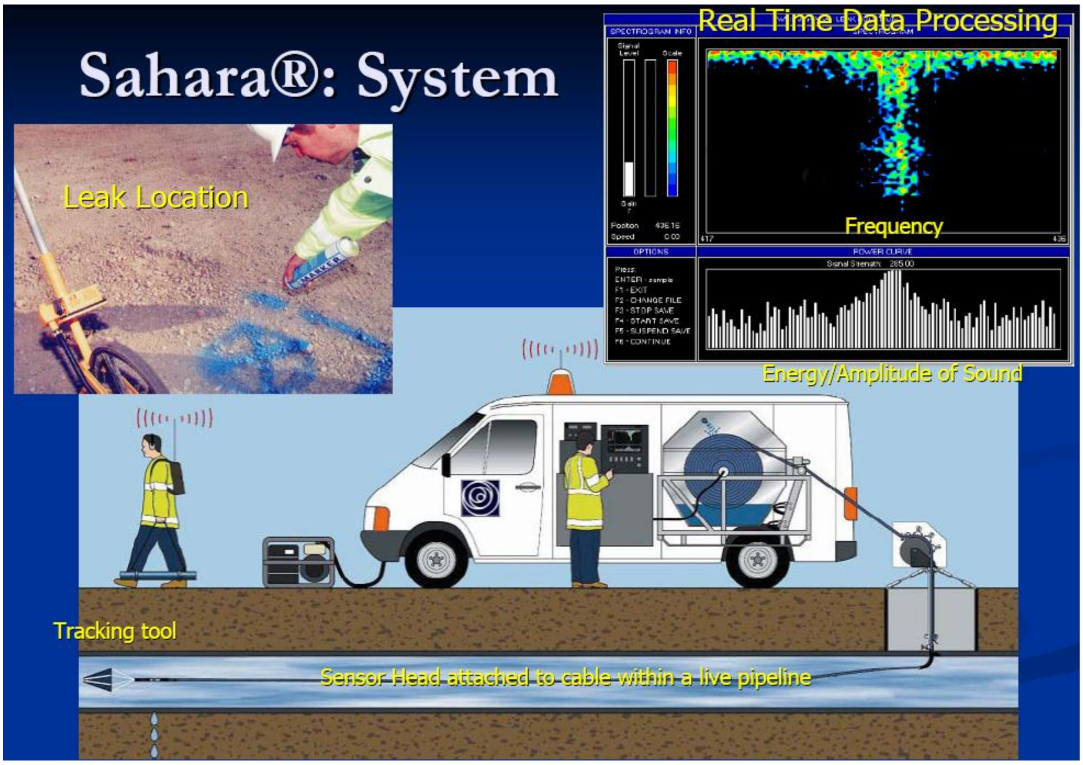

Figure 4.1.5.1 Illustration for the operation of Sahara system.

The covers to the insertion chamber will be lifted to allow venting and assessment.

Equipment scheduled for contact/entry into potable lines will be sterilized as appropriate.

- Sodium Hypochlorite (Chlorine) at 1000pm for direct contact.
- Sodium Hypochlorite (Chlorine) at 500ppm for bathed cable.
- Flow and pressure reading will be logged at the point of insertion.

A drogue (parachute), appropriate to pipeline diameter and flow, will be attached to the sensor head.

The launch assembly will be attached to the insertion point.

The drogue and sensor head will be loaded and sealed into the launch assembly.

The insertion point valve will be opened and the sensor head will be launched into the pipeline.

Once the sensor head has been deployed, the hydraulic winch unit will be mounted into the launch assembly.

The cable will be spooled out, as required, to allow the pipeline to be surveyed.

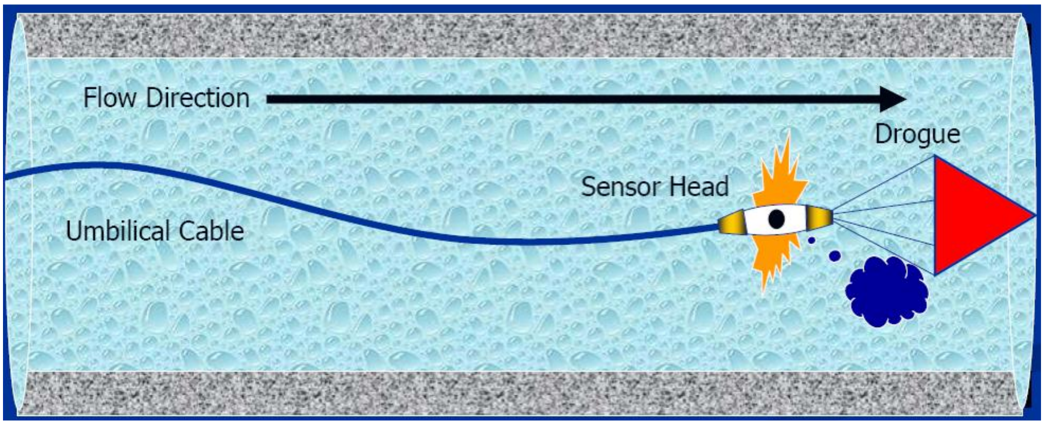

Figure 4.1.5.2 The drogue used to propel the Sahara sensor through the pipeline.

One operator will remain at the insertion point to control the equipment and monitor the survey.

Another operator will track the sensor position from the surface.

All leaks detected will be logged for report and their locations will be marked on the surface.

The cable will be retracted periodically to confirm the retrieval strain.

Surface distance will be dependent upon cable length, pipeline velocity and configuration.

Upon the completion of maximum survey length, the cable and sensor head will be retracted.

The insertion point valve will be closed and the launch assembly removed.

The survey team will report the finding, pack up the equipment and vacate site.

4.4 Monitoring of the system

Permanent Noise Logging
Loggers shall be deployed throughout the distribution system in each Waste Detection Area (WDA) or District Metered Area (DMA). They shall be able to provide continuous monitoring of leakage and give immediate responds when required.

Loggers shall be able to be placed inside chambers and to be attached onto pipe fittings. The loggers shall be immersion tested and are able to last for long duration. Leaks (signals) recorded by the logger will be transmitted to a collector via a remote control system. Whenever leak is suspected, alarm will be on and pinpointing shall be followed up.

To en-long the battery life, logger shall be in “sleep” mode in no leak situation and being activated once leak is suspected. Leak information shall be passed to a GIS data center for storage via the traditional way or via GPS on site when leak is found.

5. POST-SURVEY DATA PROCESSING

5.1 Reporting

Result of leak detection of water mains shall include all necessary information including:

Layout plan shows the alignment of the pipes and location of manholes.

A report consists of mandatory information (date and time, location, total length, number of setups of survey) and results, analysis of results and suspected or confirmed leak location.

Photographs of each leak detection setup points.

Presentation of Drawings

The investigation results (layout plan only) shall be plotted in 1:100 scale or other scales in A1 drawings on the specified grid and datum approved by the Engineer. The layout, border and title block shall be approved by the Engineer.

The drawings shall show building lines, roads with road names and traffic lane road markings, pavement and kerbs, and other significant physical features within the investigated area.

Preliminary and Final Report

The Utility Surveyor shall examine, analyse, process and interpret the investigation results and incorporate findings in a report. The report shall include the following essential information:

Introduction

(1) Project name and Location
(2) Site appreciation

Details of Investigation

(1) Date of Investigation
(2) Detailed description of the investigation procedure adopted
(3) All equipment used for the investigation
(4) Identification of supervisor and equipment operators carrying out the investigation.

Investigation results

(1) Summary of results
(2) Report on examination, analysis and interpretation of the investigation results;
(3) Identification of utilities, chambers (including all manholes) and sub-surface anomalies (if possible by GPR survey);
(4) Records of on-site verification of data handled by the qualified person (MHKIUS) responsible for the Report;
(5) Report on difficulties encountered.

Appendix

(1) Floppy diskettes or CD-R for the digital data files of qualitative and numeric data about the underground assets found;
(2) Engineering Drawings (updated) showing the types and location of various underground assets;
(3) Survey Photographs - 3R colour photographs (prints and negatives/digital copy in JPEG format)
(4) The drawings and textual report will be certified and stamped by the qualified person responsible for the preparation of the Report.

5.2 Quality control

The quality control procedures and the level of accuracy shall be agreed with the client prior to the commencement of any contract. Quality control is essential to maintain the quality of the survey as well as the professionalism of the industry.

Surveys for investigating the buried water carrying services may involve the use of special equipment and techniques, specific knowledge is required for making judgment based on the information available. Employing qualified and experienced personnel to carry out the survey gives a certain level of guarantee on the quality of the survey. The personnel requirements of carrying out the surveys are stated in section 3.4 in this guide.

The easiest and most direct way to verify the survey result of water leak detection is exposing the section of water main at the suspected leak location. As the sound cannot be retrieved in the office, the quality check shall be carried out on-site. The accuracy of the survey can be ensured by resurveying using alternative methods. Certain number of site check shall be carried out by other teams in random basis.

Confirmation of LNC result can be performed by exchanging the position of the blue and red transmitter and repeat the survey to see if the result/ the position of the suspected leak point agree with the previous one. Also, qualified leak detection specialists can be employed to reconfirm the leak position using mechanic leak detectors. Other methods like noise loggers can also be considered if appropriate.

5.3 Rehabilitation

Rehabilitation work shall be decided by the Engineer. Any suspected point of leakage shall be further investigated in details immediately. Priority shall be set according to the severity of the leak and its threat to the stability of the slope. Suitable method of rehabilitation shall be applied according to the condition of the pipes and slopes.

Replacement or repair of defective pipes can be carried out by open excavation and trenchless technology. Open excavation is the most direct way and a low-cost method for rehabilitation. However, it causes nuisance and inconvenience to the public due to the temporary traffic arrangement that may block roads. Also, nearby utilities are vulnerable to damage during excavation and when they are exposed. Safety issue is another concern when digging the pipes as hazardous gas may present in manholes and underground utilities.

Trenchless technologies involve a higher cost but cause less interruption to the environment. Joint grouting, relining using epoxy impregnated liner, relining using pre-deformed polyethylene liner, relining using smaller pipes, pipe bursting, etc. are some trenchless technologies used in pipe rehabilitation. Each method has advantages and drawbacks that shall be considered carefully before applying.

Sewer Rehabilitation Manual (WAA/WRc) and Guide to Pipe Rehabilitation by Trenchless Technology, (UTI) illustrates details about methods, planning and implementation of the rehabilitation works. The former based on the situation of U.K. while the latter based on the situation of Hong Kong.

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<u>**Appendix A: Abbreviations**</u>

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

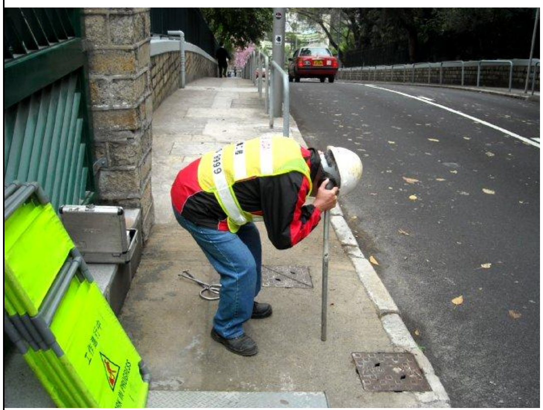
Company/ Organization	
W	Width
WLD	Water Leakage Detection
WO	Works Order
WP	Work Procedure

Appendix B: Related Photographs

A: Water burst from a deteriorated water main.

B: Finding out the alignment of the mains before leakage detection.

C: The LNC set is collecting the sounds of the pipe.



D: Manual listening by experienced operator gives a reliable result.

E: Hole drill for gas leakage detection.

F: A noise logger is installed to collect leak sounds.

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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.

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WLD

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