Guide to Pipe Rehabilitation by Trenchless Technology

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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 practices of pipe rehabilitation by trenchless technology and introduces different stages of pipe rehabilitation using trenchless technology(非開挖工程技術喉管修補). It is intended to be used by all personnel involved in the works of rehabilitating water or sewage pipes.

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April, 2011

Table of Content

Table of Content....4
1. INTRODUCTION....5
1.1 Objective and Scope....5
1.2 Hong Kong's Situation....5
1.3 Division of Trenchless Rehabilitation Methods....5
1.4 Design Consideration....6
1.5 Pipe Materials....7
2. GENERAL REQUIREMENTS....11
2.1 General....11
2.2 Statutory requirements....11
2.3 Safety Requirements....12
2.4 Contractor and Personnel Requirements....13
2.5 Equipment Requirements....13
2.6 Standards....13
3. WORKING PROCEDURES....14
3.1 General....14
3.2 Pre-lining Procedures....14
3.3 Lining Procedures....15
3.4 Post-lining Procedures....17
3.5 Quality Controls....19
4. CONCLUSIONS....20
REFERENCES....21
Appendix A: Abbreviations....22

1. INTRODUCTION

1.1 Objective and Scope

Underground utility systems in a modern city are more complicated than a spider's web. These systems are essential facilities for well operation of a modern city. In Hong Kong, portable and salt water are supplied through mains more than 7200km long while sewage is drained via a network over 1525km long to maintain our daily living. However, 45% of the underground system are built years ago and approach the end of their service life. As time passes, these once competent underground pipes have deteriorated and are difficult to maintain without any action taken. Their efficiency and reliability decline due to the numerous defects accumulated. Therefore, rehabilitation of pipelines has become an unquestionable necessity.

In this guide, we attempt to provide recommendations on good practices and specifications of trenchless pipe rehabilitation methods to enhance the quality of pipe rehabilitation. There is a bunch of trenchless lining methods and different methods have their own characteristics. The guide aims to briefly introduce the various lining methods and provide standardized processes of the linings. With the recommendations on different pipe lining methods, we hope that water pipe and wastepipe rehabilitations can be more time and cost effective and related pipe incidents can be reduced. Hence, social resources can be saved and, more importantly, properties and casualties from pipe problems can be avoided or minimized.
The guide targets to be used by all personnel who are involved in the planning, commencement and supervision of lining, including contractors, utility companies, consultants, government departments and other parties concerned. Nevertheless, it shall be noted that this guide does not include every detail of trenchless pipe rehabilitation. For the reason, the users of this guide shall refer to other relevant documents for the further information which is not included or detailed enough in this guide. Moreover, 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.

1.2 Hong Kong's Situation

With around 94 per cent of flat useful land being occupied, Hong Kong has adopted trenchless rehabilitating technologies since the 90s of last century.

In 1998, trenchless technology was first used on a large scale water mains installation program in Hong Kong, sparking the current boom in no-dig techniques. Started from 2000, another program which aims to replace or renew approximately 3,000 km (40%) of the water mains is undertaken. The program is scheduled to be completed in 2015 and is one of the largest pipeline rehabilitation programs in the world. The main trenchless techniques for replacement and renewal of mains are pipe ramming, pipe jacking, horizontal directional drilling, close-fit pipe lining (CFP), cured-in-place pipe lining (CIPP) and pipe bursting method. Apart from the mentioned technologies in the program, other technologies such as spirally wound lining, deformed lining, etc. are also widely applied by Hong Kong utility companies and government departments for pipe rehabilitation.

1.3 Division of Trenchless Rehabilitation Methods

After pipes have operated for certain years, their performance declines and problems occur. Problems can be in structural aspect such as occurrence of cracks and fractures or a non-structural type such as corrosion. According to the nature of problems, lining methods are classified. ISO standard is adopted by American Water Works Associate (AWWA) and includes 3 categories: structural, semi-structural and non-structural. In "Sewage Rehabilitation Manual" of WRc, lining is divided into type I and type II. For type I, the lining, grout (if any) and existing host pipe form a

bond to act as a rigid composite section while for type II, there is no bond among the three (if grout presents) and the lining is a flexible pipe.

Apart from the above classification, in "Trenchless Technology: pipeline and utility design, construction, and renewal" published by McGraw-Hill Companies, the trenchless technologies is classified as two main types: trenchless construction methods (TCM) and trenchless renewal methods (TRM). TCM includes all methods for new pipeline installation while TRM includes all the methods for rehabilitating the existing old pipelines. The details of the further divisions are shown in Figure 1.1.

TRM is further divided into a total of ten categories. Our discussion will focus on several linings of TRM.

1.4 Design Consideration

As introduced by "Sewage Rehabilitation Manual" of WRc, the whole rehabilitation can be separated into four stages as shown in Figure 1.2. Planning and diagnostic stages aim at defect identifying. Solution development and implement stages aim at rehabilitating the pipe system.

After recognizing the problems in a pipe system and considering the virtual situation of various aspects, the most economic solution can be taken to tackle the problems. The means to estimate the cost of a rehabilitation project can refer to "Trenchless Technology: pipeline and utility design, construction, and renewal" published by McGraw-Hill Companies or "Sewage Rehabilitation Manual" published by WRc.

Cost is only one of the parameters. Other parameters or factors including the types of defects, gravity or pressure pipeline, types of flow carried, pipe diameter, pipe length to be lined, pipe shape, existence of bends, the external load, the surrounding soil, the design/ service life, etc. Table 1.1 shows the types of linings matching various parameters or factors.

Rehabilitation design is a complex process. The developed solution shall be pipe condition specific and meeting project needs. Therefore, designer's knowledge, experience and the understanding of the host pipe system to be rehabilitated are vital in developing a successful solution. For further details about design considerations, one may refer to "Trenchless Technology: pipeline and utility design, construction, and renewal" published by McGraw-Hill Companies or "Sewage Rehabilitation Manual" published by WRc.

1.5 Pipe Materials

One of the design considerations is choosing appropriate material as the liner pipe. Factors in the primary consideration are the decided lining method and the expected design life. A design life of 50 years is usually expected but the expected life can be as long as 100 years in some cases. Then corrosion and abrasion resistances are considered. It is related to the soil load, pipe-soil interaction, the type of fluid being contained, etc. Other factors include pipe diameter, installation length, ease of installation, etc. Table 1.2 shows the types of lining matching with the lining materials.

In a pipe rehabilitating project, the material applied shall strictly follow the specification and standards (e.g. ANSI/ AWWA, ASTM, WIS or CESWI) stated in the contract document to achieve the required designed life. Moreover, the test result of the lining material (e.g. chemical corrosion resistance test) by third parties or from the liner Manufacturer shall be included in the final report to the Client.

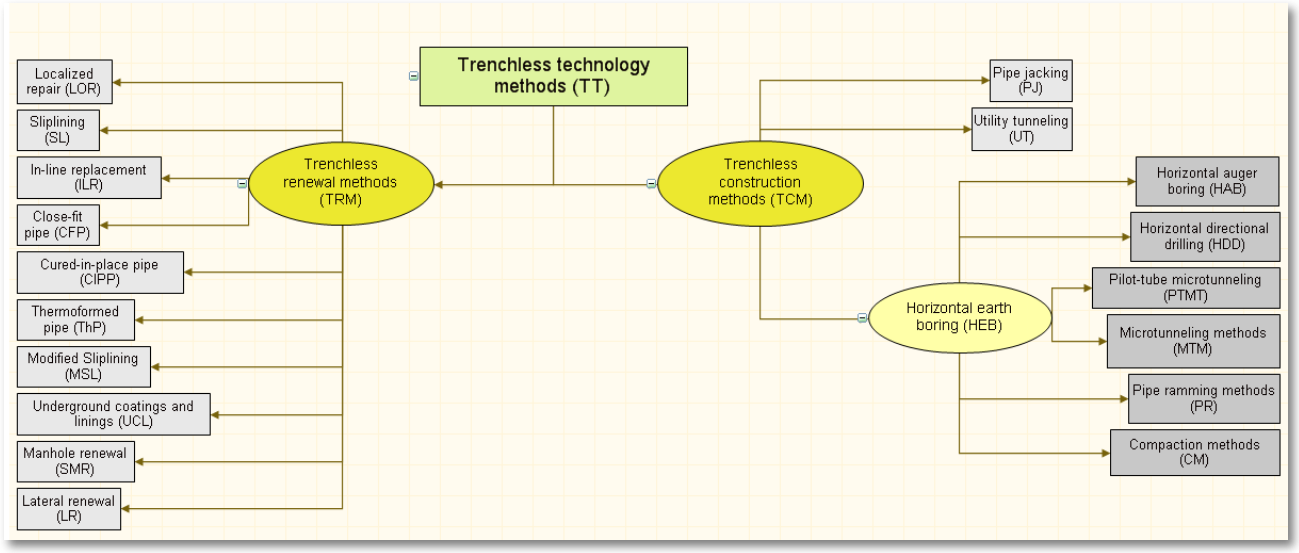

Figure 1.1 Chart of Trenchless Technology Division

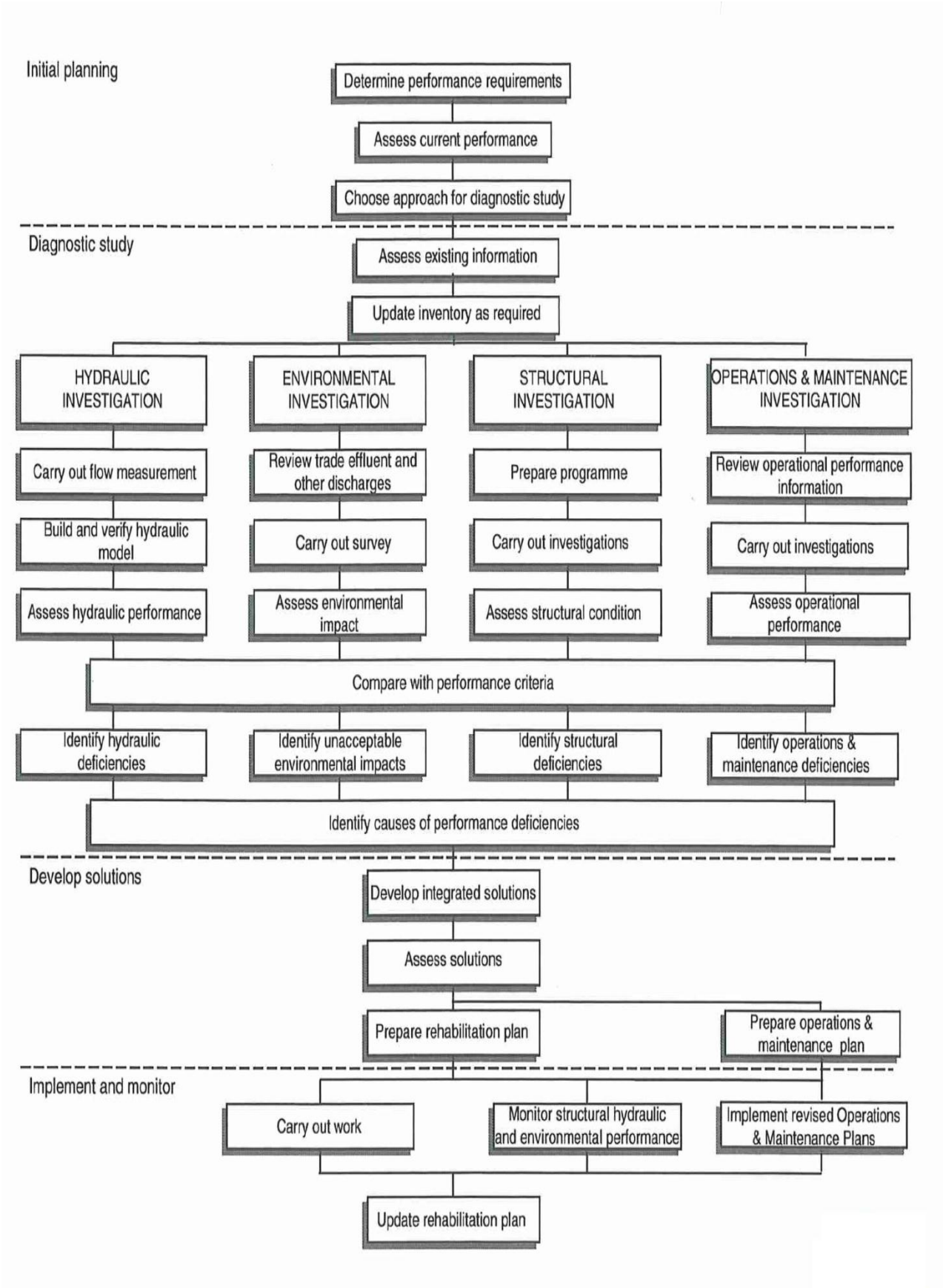

Figure 1.2 Stages of pipe rehabilitation (Adopted from "Sewage Rehabilitation Manual", 2001, published by WRc)

Pipeline type / Rehabilitation method	CIPP	SL	ILR	CFP	SWL	PL	FIPP	ThP
Pressure pipeline	Y	Y	Y	Y				Y
Gravity pipeline	Y	Y	Y	Y	Y	Y	Y	Y
Portable water pipe	Y	Y	Y	Y				Y
Sewer	Y		Y	Y	Y	Y	Y	Y
Gas pipeline		Y	Y	Y				Y
Chemical or industrial pipe	Y	Y	Y	Y	Y	Y	Y	Y
Circular pipe	Y	Y	Y	Y	Y	Y	Y	Y
Noncircular pipe	Y		Y		Y	Y	Y	Y
Straight pipelines	Y	Y	?	Y	?	?	?	Y
Pipeline with bends	Y	Y	Y	Y	Y	Y	Y	Y
Pipeline with varying cross sections	Y		Y		Y	Y	Y	Y
Pipeline with deformations and misalignment	Y	Y	Y		Y	Y	Y	Y
Pipeline with lateral connections	Y		Y	Y	Y	Y	Y	Y

Table 1.1 Application of different lining methods

Index:
? Not Sure
Y Applicable
CIPP Cured-in-place pipe
SL Sliplining
ILR In-line replacement (pipe bursting, pipe removal, pipe insertion)
CFP Close-fit pipe
SWL Spiral Wound Pipe (Modified Sliplining)
PL Panel Lining (Modified Sliplining)
FIPP Formed-in-place Pipe (Modified Sliplining)
ThP Thermoformed pipe

Lining methods	Diameter range (mm)	Installation length (m)	Pipe Materials
CIPP (inverted in place)	102 – 2743	76	Thermoset resin/ fabric composite
CIPP (winched in place)	102 – 2540	38	Thermoset resin/ fabric composite
SL (segmental)	588 – 3920	25	PE, PP, PVC, GRP
SL (continuous)	392 – 1543	25	PE, PP, MDPE, PVC
CFP (structural)	74 – 588	25	HDPE, MDPE
CFP (non-structural)	74 – 1543	25	HDPE, MDPE
SWL	63 – 1000	1000	GRP, PE, PVC
PL	Above 1176	Varies	PE, PVC, PP, PVDM
FIPP	196 – 3528	Varies	PVC, HDPE
ThP	98 – 735	37	HDPE, PVC
ILR (pipe bursting)	98 – 1176	37	PE, PP, PVC, GRP
ILR (pipe removal)	Up to 882	7	PE, PVC, PP, GRP
ILR (pipe insertion)	Up to 588	12	Clay, ductile iron

Table 1.2 Characteristics of different lining methods

Index:
LDPE Low density polyethylene
MDPE Medium density polyethylene
HDPE High density polyethylene
PP Polypropylene
PU Polyurethane
GPR Glass reinforced plastic

2. GENERAL REQUIREMENTS

2.1 General

There are several general requirements shall be noted when carrying out a pipe lining project including statutory requirements, safety requirements and personnel requirements, etc. Moreover, a comprehensive working plan and a safety plan shall be prepared for the success and smooth of rehabilitating process. All measures in the process shall follow the specifications stated in the Contract or relevant standards.

2.2 Statutory requirements

There are different statutory requirements on different areas. One shall refer to contractual documents and other guides for details. Information can also be obtained from a number of organisations, e.g. the Hong Kong Institute of Utility Specialists (http://www.hkius.org.hk). The following is a brief introduction on some most common ones.

- **Health and safety**: the Workplace Health and Safety Regulations of Hong Kong specify 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, etc. It is important to follow relevant ordinances stated in the Occupational Safety and Health Council (http://www.oshc.org.hk).

- **Noise**: the Noise Control Ordinance (Cap400) shall be complied with and Construction Noise Permits shall be obtained for noise disturbance may arise during project.

- **Traffic**: Some linings require working area of certain size to prepare the liner and TTA is required. In those cases, the Code of Practice for Lighting, Signing and Guarding of Road Works published by the Highways Department shall be complied with and the Road Liaison Officer of the Hong Kong Police Force shall be liaised.

- **Excavation**: For the excavation of pits, Excavation Permits from the Highways Department shall also be applied. The access around the excavation 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.

2.3 Safety Requirements

Both Contractors and site workers 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. As mentioned above, it is important to follow relevant ordinances stated on the Occupational Safety and Health Council (http://www.oshc.org.hk).

Generally, the employer and the contractor have to prepare a safety plan and have risk assessment being carried out by trained safety personnel before the commencement of work. The safety plan shall have regarded to the Government's Construction Site Safety Manual and to UK's Water Industry's National Joint Health and Safety Committee's publications. Apart from conducting risk assessment for the work safety, the effect on the public shall also be evaluated. Appropriate steps shall be taken to minimize or even eliminate any potential risks for injuring the public.

Moreover, all staff working on the Site has to be given with general safety and health training as well as Personal Protective Equipment (PPE) and shall have sufficient knowledge in both usage and maintenance of that 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

Since manhole or pit works are necessary, therefore, the Code of Practice: Safety and Health at Work in Confined Spaces and DSD's Practice Note No. 1/2007 for working in confined space shall be strictly followed. A "Permit and Enter" system in accordance with the Factories and Industrial Undertaking (Confined spaces) Regulations shall be operated.

2.4 Contractor and Personnel Requirements

The Contractor of a lining project is suggested to have successfully managed and completed rehabilitation projects on lines ranging in size from smallest line on the project to the largest line on the project within the last three years before bid date. In the absence of this experience, the Client may require that the Contractor install a Demonstration Project as defined by the Client using the same system to be proposed prior to bidding on a particular project.

In order to maintain the Utility Profession's requirements for the consistency, reliability and accuracy of project implement and reports, pipe rehabilitation 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. Table 2.1 states indicative guidelines on the training and experience requirements. Besides, qualified personnel are required to attend refreshment course in every 3 years to refresh and enhance their knowledge.

Type of Personnel	Role	Minimum Training Requirement	Minimum Years of Experience
Project Leader (M/ FHKIUS + RPUS)	Contractual arrangement, check and certify reports.	Training courses for utility survey/detection methods and data management.	10 years in contract administration, preferably in utility survey.
Team Leader (M/FHKIUS)	Works arrangement, check data quality and consistency.	Training courses for utility survey/detection methods and data management.	10 years in works of utility survey.
Crew Leader (O/MHKIUS)	Supervision of field works and site safety.	Training course and valid training certificate for utility survey.	5 years in works of utility survey.
Operator (AMHKIUS)	On-site inspection and operation of equipment.	Training course and valid training certificate for utility survey.	3 years in works of utility survey.

Table 2.1 Training and Experience Requirements for Personnel Carrying out Pipe Rehabilitation (Reference to the Code of Practice on Monitoring and Maintenance of Water-carrying Services, Work Branch, 2006 and HKIUS constitution, 2010)

2.5 Equipment Requirements

Different lining methods require different equipment. The requirement for the equipment for a particular lining varies with the situation of the pipeline to be rehabilitated. Therefore, there is no general standard for all lining equipment except that the equipment shall be well-prepared and checked working two weeks before project starts. One shall always follow the specifications stated on the Contract.

2.6 Standards

There are different specifications and standards for different sections of different linings. Standards of ASTM International and/or European Standards, EN, i.e. including CEN, CENELEC and ETSI, are suggested to follow or take as a reference. One shall always follow the specifications and standards stated on the Contract.

3. WORKING PROCEDURES

3.1 General

The applied liner materials and working procedures of different lining methods vary from each other. However, their pre-lining procedures and post-lining procedures are similar.

3.2 Pre-lining Procedures

The pre-lining processes include reconnaissance survey, pit excavation, pipe cleaning of the host line, CCTV inspection and over pumping.

In all linings, a reconnaissance survey is normally required for creating appropriate working plan and safety plan and evaluating if the currently suggested lining method is practical. In a reconnaissance survey, the existing features of the pipeline to be lined are compared with that on a Layout Plans. Any features not shown on the Layout Plans shall be recorded. The surrounding and the surface conditions of the existing pipeline are evaluated to check if the proposed lining method is appropriate. Manholes of upstream and downstream shall be especially checked if they are fit to act as the launch pit and reception pit. Otherwise, excavations at right points shall be implemented. Working area is needed for liner preparation and insertion so area around the chosen points shall be checked to be enough as well. A temporary traffic arrangement (TTA) may be required when the lining is on a traffic road. The reconnaissance survey shall be conducted by Competent Person or under the supervision of Competent Person.

Prior to liner installation, thorough cleaning for the existing pipe is essential to remove all internal rust, greases, tuberculation, deposits, debris, remains of the original internal coating and foreign intrusion like roots which can hinder a smooth lining installation process. High pressure water jetting is a commonly used method to promote bond between liner or grout and the inner wall of existing pipe. ASTM E1575 - 08 Standard Practice for Pressure Water Cleaning and Cutting or specifics stated in the Contract shall be followed. Subjected to the condition of the host pipe, other hydraulic methods like balling or flushing or other mechanical methods like rodding may be applied for cleaning. For details, one may refer to "Trenchless Technology: pipeline and utility design, construction, and renewal" published by McGraw-Hill Companies. Besides, man-entry cleaning may be carried out if pipe is large enough and the rehabilitation is semi-structural or non-structural, i.e. safe condition. The Contractor shall ensure that the cleaning method and the cleaning process do not lead to any further damages to the existing pipeline.

After cleaning, the pipeline shall undergo a CCTV inspection and a video shall be taken. The pipeline is inspected prior to installation so that the pipe material, condition, level of cleanliness, and all existing bends are checked. All defects shall be noted. If there are any openings or connection in the middle of the pipe, their positions and sizes shall also be noted and measured. They shall be closed and rendered non-operational before installation. If the inspection shows an obstruction not indicated in the record plans or specifications that cannot be removed by conventional cleaning, the Contractor shall notify the Engineer. The Contractor of the lining project shall provide sufficient CCTV inspection equipment in full working order and submit the result of the initial CCTV inspection recorded on a DVD disk and report to the Engineer. For more details of CCTV inspection, one can refer to "Particular Specification For Conduit Condition Evaluation (CCTV and Man Entry Survey)(2011)" from Hong Kong Institute of Utility Specialists, Hong Kong.

In some lining installations, no flow diversion or only partial flow division is required since existence of flow in the host pipe enhances the insertion, such as sliplining. On the other hand, for

certain other linings or for safety consideration under a high flow situation, complete flow diversion is essential. For sewers or stormwater pipeline, the peak flow shall be estimated or predicted so that maximum pumping rate or flow rate can be avoided since over pumping is costly. When required, the flow is controlled at the sections of pipe to be lined by plugging pipe of bypass system at an existing upstream manhole or pit and over pumping the flow into a downstream manhole, pit or adjacent system.

3.3 Lining Procedures

Since the lining procedures for different linings are not the same. The methods of cured-in-place-pipe (CIPP) lining, sliplining, Close-fit-pipe (CFP) lining and modified sliplining are shortly introduced in this guide only. One may refer to the manual of this guide which is planned to be published by HKIUS or other relevant references for the detailed lining procedures and information about more other linings.

LINING TYPE	INSTALLATION METHOD	STANDARDS
CIPP	1. Flexible fabric or fiberglass tube is resin-saturated to become liner 2. The liner is inserted into host by water inversion or air inversion or winch pulling 3. After inflating, the liner is cured to form new pipe by hot water or steam or Ultra-Violet light	ASTM F1216 ASTM F1743 ASTM F2019 ASTM F2599
Sliplining	1. The liner pipe sections are joined by butt fusion or flush sleeve joint to form a continuous liner at pit site or in factory 2. The liner is inserted by winch pulling, or hydraulic machine pushing or both 3. Lateral reconnections if any 4. Grouting	ASTM F477 ASTM F585 ASTM F2620 ASTM D3261 ASTM F2561
CFP (deformed method)	Liner is deformed into "C" or "U" shape at site or in factory after fusion joining The liner is inserted into host pipe by winch pulling The liner reverts to form a close fit with host pipe via natural relaxation or applying pressurized cold/ hot water or air or steam	ASTM F1533
CFP (reduced-pipe-diameter method)	Liner sections are butt fused to become a continuous liner Liner's diameter is hot or cold reduced by hemispherical roller or tapered steel reducing die The liner is inserted by winch pulling The liner returns to its original size by natural relaxation or applying pressurized cold water or air	
Modified sliplining (spiral wound lining)	Liner strip with tongue-and-groove castings is fed to a winding machine The hydraulically driven winding machine hydraulically winds the strip into host pipe The edge of the strip is locked to form a continuous helically wound liner Depending on situation, the annular space is grouted	ASTM F1697 ASTM F1741
Modified sliplining (panel lining)	GPR panels are manufactured to fit the shape of the host pipe Panels are transported by hydraulically driven self-propelled trolley to position of installation within host pipe Installation is manually done	

3.4 Post-lining Procedures

Post-lining procedures includes cool down process, trimming the liner ends, cleaning the new pipe, lateral reconnection, CCTV inspection and finally handing in the report to the Client.

If the liner undergoes heating up process during lining, such as CIPP lining, there shall be a cool-down process or period to allow the liner to resume the environmental temperature or temperature recommended by manufacturer. Accompanying heating process, internal pressure is usually built within liner. Cool-down shall be done before any internal pressure being released to avoid sudden drop of internal pressure damage the newly formed pipe. The cool-down may be accomplished by the introduction of cool air or water into the section to replace the original heated air or water inside. The steam or hot water shall be drained from a small hole made in the downstream end.

For the rehabilitated pipe with connections in the middle, dimples can be created at the connecting locations due to applied pressure during lining process. A robot cutting device with CCTV is generally employed for reopening after a 24-hour relaxation period for liner. For pipe with a large diameter, reopening may be done by man-entry under safe condition. The lateral connections shall be reconnected internally up to a minimum of 95% fully reopen and trimmed to a neat, clean, circular opening concentric with the service line pipe. For sliplining, the lateral reconnections shall be done before grouting.

After installation, the remains during the lining process shall be drained out. The discharge shall be disposed according to relevant regulations. The ends of the new pipe shall be tidily cut and trimmed. A final color CCTV inspection on the rehabilitated pipes shall be done to check the acceptability of the works. The CCTV inspection shall be performed by experienced personnel trained in defect locating.

Afterwards, a full report shall be handed in to the Engineer or the Client generally not later than 2 weeks after the completion of the work. The report shall include the following items:

- A full description of the applied lining method
- The description and details of all the equipment and materials used in the lining process
- Manufacturer's catalogues and data of the lining material and equipment used and the related standards and specifications followed in the lining process
- The details of the lining operation process
- The logged temperature and pressure data during and after installation of the liner
- The post-installation condition of the manholes and pits
- The post-installation CCTV video records and cleaning and CCTV report
- The post-installation verification test result report on the material of the new pipe
- The post-installation test result report on the strength and hydraulic pressure standing of the new pipe
- The result report of the hydraulic performance of the new pipe
- The result reports of other quality controls

3.5 Quality Controls

There shall be quality control measures during and after installation of liner to ensure the quality of the lining. These include the proper storage of the liner, the temperature and pressure monitoring during lining, the post-installation CCTV inspection and various post-installation tests. The quality control measures applied are subjected to the lining method applied.

Most liners are manufactured in factory. During the transportation to site and before installation, the liner shall be well stored within a refrigerator truck or other environment that the temperature is kept at manufacturer's recommendation to avoid any prematurity. At the time of delivery, the liner shall be kept homogeneous, uniform in color, free of cracks, holes, blisters, deleterious faults and foreign materials. Liner with problems found shall not be used.

For linings involving heating up process and application of pressure, the internal temperature and pressure of the liner shall be monitored and recorded and kept as the recommendation of the liner manufacturer or the specifications stated in the Contract. This is achieved by remote sensors and monitors usually placed between the liner and the preliner or the host pipe at both invert ends. The logged data of temperture and pressure shall be submitted to the Engineer or the Client.

After installation, a CCTV inspection shall be conducted by visually check to ensure the quality of the new pipe is within an acceptable range. For an acceptable new pipe, the wall color of the interior pipe surface shall be in a reflective color so that the details can be clearly seen via CCTV. There shall also be no observable defects such as foreign inclusion, dry spots, pinholes, leaks etc.

Apart from CCTV inspection, there are several quality control tests for a new pipe:

- Test of pipe wall thickness
- Test of pressure standing ability
- Test of flexural modulus and strength
- Test of hydraulic performance
- Post-installation verification test of pipe material (upon to client's request)
- Other tests

The new pipe's wall thickness shall be checked to be homogenous and meeting the designed thickness and no delamination across the whole lined line. There shall be no intermediate or encapsulated elastomeric layers since no material that causes delamination shall be included in the liner tube. The wall thickness shall be measured and the Standard Dimension Ratio (SDR) shall be calculated to ensure the tender requirement on the wall thickness is not violated. During thickness testing, the thickness of preliner tube shall be removed and excluded.

ASTM standards and EN standards can be adopted for tests on the mechanical properties of the new pipe.

4. CONCLUSIONS

Hong Kong is a crowded place so trenchless lining becomes very popular since its first introduction in Hong Kong in 1990s. There are no general standards on which lining methods shall be applied to which situation. The lining method being chosen is subjected to the actual site conditions and the host pipeline's condition. The challenge of a pipe rehabilitation project can be a technical one, a material one or site condition one. The determination of lining method shall be considered case by case and depends on the experience and knowledge of the Contractor.

In this guide, several major lining methods are introduced in short. One may refer to other relevant specifications or standards or references for further details of a particular lining method when conducting a lining project.

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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

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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

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