

Inspection of partially filled conduits

Many system operators are confronted in the case of partially filled conduits with the question of „How do we inspect it?“. In the context of a pilot project, the IKT and the *Stadtentwässerungsbetrieb Paderborn* (Paderborn Municipal Drainage Corporation; German abbreviation: StEB) have examined a range of different inspection options. The results have now been published.

Determination of system condition

Existing regulations, such as the *Selbstüberwachungsverordnung Kanal* (Self-monitoring Ordinance for Drain and Sewer System Operators, German abbreviation: SÜwV Kan) applicable in the German state of North Rhine-Westphalia (NRW), oblige system operators to survey and determine the condition of their entire conduit system at regular intervals. Many operators have not insignificant doubts in the case of partially filled main drains, in particular, for which reason numerous operators have not yet established the condition of these conduits (see [1]).

Due to a lack of suitable strategies and methods, the StEB had not inspected its main sewer since its commissioning in 1981. The company therefore initiated, jointly with the IKT, the „Inspection of partially filled conduits“ pilot project [2]. The concluding report, containing detailed results, is available for download from the Internet: www.ikt.de

Practical deployments and IKT test sections

A number of solution variants for optical inspection of a 5.7 km long part-section of the Paderborn main sewer (total length: 8 km) were to be drafted and implemented.

IKT monitored and documented ten practical deployments in Paderborn. The knowledge gained was evaluated in terms of advantages and disadvantages, in order to determine any available margins for improvement, and the

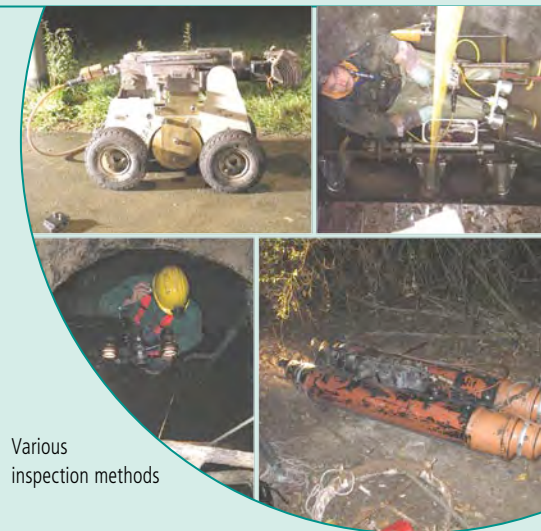
potentials and limitations for practical use of the various techniques tested. The results will make it possible to provide conduit-system operators with orientational data for the preparation of the planning of future systems in a manner permitting accurate inspection.

Tests in IKT test sections

Tests were performed in partially filled IKT test sections in order to examine under repeatable boundary conditions methods of lowering the water level and inspecting the bottom area of the pipe interior. Two techniques, in particular, were used:

- An ejector, to lower the water level and
- A pressure chamber for optical inspection of the bottom of the pipe interior

Ejector: an ejector (Figure 1) did, indeed, make it possible to significantly lower the water level, but not to keep the bottom of the pipe interior completely free of water. In addition, the water-spray and formation of aerosol observed during performance of these tests can also have



Various inspection methods

a negative effect on the quality of any optical inspection performed in parallel.

Pressure chamber: a pressure chamber open at the bottom (Figure 2, next page) was set up in the IKT experimental section, which was flooded with simulated waste-water. This water was expelled, in one case, by air (Variant A) and, in the other case, with clear fresh water (Variant B).

In Variant A, the level of the simulated waste-water in the pressure chamber was, indeed, lowered significantly, but not completely. Optical inspection of the bottom of the pipe appears to be at least partially feasible using Variant A. Potentials for improvement do, however, remain, with respect to the lowering of the water level and the avoidance of water spray.



Figure 1: Use of a large-section ejector nozzle in the IKT test conduit section; Left: Lowering of the water level from 20 to 12 cm; Right: Turbulence and water-spray behind the nozzle, height: approx. 60 cm



Figure 2: Elements and dimensions of pressure chamber
Top left: Individual elements: side-walls, top;
Top right: Overall view along the pipe
Bottom: Side-wall with compressed-air connection;

Implementation of Variant B indicated that the simulated waste-water could not be adequately expelled from the pressure chamber using fresh water obtained directly from the potable-water main. Inspection of the bottom of the pipe was therefore not possible.

In-situ inspections in Paderborn

A detailed „Actual“ survey was performed prior to the inspections. This procedure consisted of a number of operations; these are described in detail in both the complete and the abbreviated version of the report (available for download at: www.ikt.de).

The project team took the Actual situation as the basis for the development of conceptual solutions and solution-variants on the topic of conduit cleaning, water control and inspection. Those procedures which, under the given boundary conditions, appeared suitable for on-site use, were then selected.

The water management concept comprised the following operations:

Inspection method			On-site deployments	Range [m]	Water level [cm]*
I	Mobile Robot A: Argus 4 ¹ with chassis ² for large-caliber pipes, photo: IKT		3	1.994	20 to 25
II	Mobile Robot B: Argus 4 ¹ with tractor mounting ¹ , photo: IKT		2	474	20 to 30
III	Mobile Robot C: Tractor P448 ³ , photo: IKT		1	(84)	30
IV	Floating robot: Argus 4 ¹ with float ⁴ , photo: IKT		2	724	20 to 25
V	Manned-vehicle access: Tractor ⁵ and Cerberus hand-held camera ¹ , photo: IKT		2	1.208	10 to 20
VI	Human access to conduit: Equipment supplied by ISAS GmbH, Füssen/Germany, photo: IKT		1	824	25 to 30
*after water management provisions; normal partial filling in operational condition approx. 90 cm			Σ 5.224 (92 % of total length)		

Figure 3: Overview of inspection deployments at the Paderborn site

- Shutting-off of a feeder into the main sewer and temporary storage of the waste-water
- Performance of the inspections in the low-influx nighttime hours between 0.00 h and 6.00 h
- Agreement of inspection dates with local industrial enterprises (which also discharge water during the night)

Six different inspection methods were used at Paderborn; these took the form of three mobile robot systems, similar to those also used for inspection of non-accessible (i.e., non-walk-in) conduits, a floating robot system and, in each case, a technical solution for manned-vehicle access and for human access to the conduit. Figure 3 shows for each inspection method the number of deployments, the length of the conduit section examined, and the water level during the inspection period.

The colour-coded markings in Figure 4 show the various sections inspected within the overall 5.7 km long sub-section. The two black zones (of lengths of 154 m and 322 m, respectively)

could not be inspected, since it was not possible to access the manhole shafts as a result of local boundary conditions. The result of monitoring of practical deployments at Paderborn was the obtainment of the following insights concerning the potential usefulness and limitations of the systems deployed under the given boundary conditions.

Floating robots

The use of floating robot is a possible option in cases in which the conduit to be inspected is relatively full at all times and the implementation of suitable water-management provisions would cause disproportionately high costs referred to expenditure for pure determination of condition. In addition, provided the water is sufficiently deep, depositions in the bottom area of the pipe interior do not obstruct this system.

Only a rough inspection is possible with this system, however, since the camera permits only visual inspection (i.e., via optical instruments) of the gas space. In addition, it must also be noted that a puller system (e.g. a winch) and a traction

¹ Manufacturer: IBAK Helmut Hunger GmbH & Co. KG, Kiel (Germany)

² Manufacturer: Pader Kanal Technik - Rohr Frei GmbH & Co. KG, Paderborn-Sennelager (Germany)

³ Manufacturer: Radiodetection Ltd., Bristol (United Kingdom)

⁴ Manufacturer: Lönne Entsorgung GmbH & Co. KG, Lippstadt (Germany)

⁵ Manufacturer: Tauchunternehmen und Apparatebau Hirt, Koblenz (Germany)



Figure 4a: Eastern section of the system inspected, inspection methods used



Figure 4b: Western section of the system inspected, inspection methods used

rope are necessary for propulsion of this inspection system. The passing of the rope through the conduit, in particular, can be time-consuming.



Figure 5: Argus 4 floating TV inspection robot (manufacturer: IBAK Helmut Hunger GmbH u. Co. KG), showing float (manufacturer: Lönne Entsorgung GmbH u. Co. KG)

Limitations on the use of this inspection method may result from waste-water turbulence, since this can result in the recording of blurred and therefore unusable video data.

Unmanned mobile inspection

Elevated flow of waste-water, and depositions or drain obstructions, can result in aborting of condition-inspection where unmanned mobile inspection systems are used. In addition, the water level also has an influence on the scope of the inspection, since, on these robots, too, the only sensor takes the form of a camera, using which the gas space can be „visually“ (i.e., optically) inspected. Against this background, low



Figure 6: Argus 4 unmanned mobile TV inspection robot (manufacturer: IBAK Helmut Hunger GmbH u. Co. KG), with chassis (manufacturer: Pader Kanal Technik – Rohr Frei GmbH u. Co. KG)

water levels and the elimination of depositions are, therefore, the precondition for successful use of mobile inspection devices. The time required for insertion of such robots into the conduit and for their removal from it is generally short, since these machines can in most cases be passed in operating condition through standard manhole openings. Greater work input can, however, occur if, for example, step irons in the manhole shafts hinder robot access, and the robot therefore has to be assembled in the shaft. The mobile inspection systems used supplied a steady video image. It was found that changes in direction in the conduit, which occurred with angles of up to 60° during the practical tests, can be safely negotiated even by non-steerable robots.

Structural details, such as side infeeds and pipe joints, were recorded by pivoting the camera and using the zoom function. It was necessary to utilize these functions throughout the inspection, however, in order to permit detailed examination of the conduit as a whole. It is to be expected that this would significantly increase the times required for inspections.

Access

It became apparent that, unlike the situation with unmanned inspection methods, the use of manned-vehicle and purely human access permitted more detailed inspection of conduit condition. Unlike camera-robots, humans perceive their environment in 3D and are capable of using their sense of touch and performing manual activities. These abilities made it possible during the manned in-conduit deployments in the Paderborn system to register even minor damage, to examine abnormalities of the conduit cross-section located in the gas space by means of tactile investigation, and to take

material specimens from the conduit structure. In addition, the inspector was also able to investigate the part of the conduit located below the water level with his feet, in order to inspect it for any significant damage or depositions.



Figure 7: Conduit entry: ISAS GmbH inspector

It is necessary, alongside the above-mentioned advantages of manned inspection methods over unmanned procedures, to take account in their use of two important factors: on the one hand, persons working in such conduits are exposed to a number of hazards; emergencies can, for example, arise as a result of toxic and/or explosive gases. Suitable safety precautions, such as ventilation of the conduit, the use of gas-warning analyzers, and the wearing of self-rescuer equipment or breathing apparatus, are necessary in order to minimize such dangers. On the other hand, the hand-held cameras used can result, depending on local boundary conditions and the expertise of the inspector, in unsteady or blurred video images. The performance of test deployments in the system to be inspected is recommendable, to permit assessment of such factors in advance.

Manned-vehicle access

In the case of manned-vehicle access, the inspector sits on a tractor, which is drawn through the conduit and is designed in such a way that its wheels run along the inner surface of the pipe above the waste-water level. This results in specific advantages compared to purely human access to the conduit: there is no danger of falls and the tractor provides the inspector with a support. Inspection of conduit condition can be performed at higher water levels and flow velocities, with no disturbance from depositions on the bottom of the pipe interior.

Purely human access, on the other hand, necessitates significantly shorter preparation times, since

neither the assembly of a tractor nor the installation of a puller system and a traction rope are necessary. Where water levels and flow rates are low, and there are few depositions, human access is the better option for detailed inspections.

Planning recommendations: Inspection



Figure 8: Manned-vehicle conduit access: inspector with tractor (manufacturer: Tauchunternehmen und Apparatebau Hirt)

The drafting of a universal model service specification for inspection of partially filled conduits appeared not to be a rational option, due to the diverse requirements for inspection of partially filled conduits, resulting, for example, from nominal diameter, section length, waste-water flow and water level. It appeared instead to be more rational to provide the responsible engineer with general notes and indications for the preparation of inspection projects and for inspection-orientated planning and design of future systems. The scope of functions includes in this context not only the selection of a suitable inspection system or procedure, but also the preparation of supplementary provisions for support of the inspection operation, such as water management or conduit cleaning, for example.

a) Actual survey

The precondition for planning is detailed knowledge of the object or system to be inspected. For this reason, the performance of a survey of Actual condition is recommended as an initial step. Examination of existing documentation, walking of the conduit route on the surface, and interviews with the drain/sewer-system operator, are all potential methods for the obtainment of the necessary information.

b) Development of solution-variants

Solution-variants for implementation of the inspection project can be developed on the basis of the survey of Actual condition in the second

planning stage. In order to lower water levels for the period of the condition-inspection, a check should be made to determine the extent to which chronological fluctuations in flow rate can be exploited, or temporary storage potentials for the backed-up waste-water implemented using pumping stations or valves. Where these options are not possible, other temporary water-management provisions must be considered, such as the use of siphons and/or mobile pumps and shut-off elements. The accessibility of the conduit will depend on the topography, and on the surfacing and utilization of the surrounding land. The insertion into the conduit of inspection equipment, pumps and shut-off elements may be facilitated (but may, of course, also be restricted) by the dimensions of the manhole opening and geometry, and the condition of the manhole-shaft structure (size and arrangement of walking surfaces, the dimensions of the working chamber and the safe condition - or otherwise - of the step irons).

c) Method selection

In the third planning stage, i.e., selection of the most appropriate method, the solution variants developed should be examined not only from the viewpoint of basic technical feasibility. It is also necessary to determine, on the one hand, the extent to which the content and qualitative requirements specified by the client, such as the following, can be met:

- Maximum permissible partial filling
- Inspection detail and accuracy
- Documentation method
- Damage-classification system
- Result format

Cost-efficiency is, on the other hand, also an important selection criterion. This factor is influenced by labour and material costs and must be set against inspection benefits. Working safety (Industrial Health & Safety) considerations must also be taken into account. Various potential hazards will result for the persons working in the conduit, depending on the method selected.

The know-how of the staff deployed is also a decisive precondition for the success of drain/sewer inspections. This criterion can be quantified only with difficulty on the basis of

company information and references. A method-based preliminary selection, combined with the performance and monitoring of subsequent test deployments in the system to be inspected, is therefore recommended.

Planning recommendations:

Construction of future systems

It remains to be noted, with a view to construction of future systems, that adequate drain accessibility at all manhole-shafts is a vital and basic precondition for an inspection, and that supporting provisions for water-management must also be taken into account. This is true, in particular, in cases in which no permanently installed shut-off equipment is available. Temporary water-control provisions generally also necessitate a high level of input for Industrial Health & Safety provisions, since even unmanned inspection inevitably involves the deployment of personnel in and around the channel in the shaft. These aspects must be borne in mind both for the planning of manhole-shaft structures and for conceptual design of the water control safety precautions.

References

- [1] Bosseler, B.; Birkner, T.: Umsetzung der Selbstüberwachungsverordnung Kanal (SüwV Kan) bei den kommunalen Netzbetreibern und Wasserverbänden in NRW; Concluding report by the IKT – Institute for Underground Infrastructure on behalf of the Ministry of the Environment and Conservation, Agriculture and Consumer Protection of the State of NRW, December 2003
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IKT - Institute for Underground Infrastructure

ABOUT IKT



IKT - Institute for Underground Infrastructure is a research, consultancy and testing institute specialized in the field of sewers. It is neutral and independent and operates on a non-profit basis. It is oriented towards practical applications and works on issues surrounding underground pipe construction. Its key focus is centred on sewage systems. IKT provides scientifically backed analysis and advice.

IKT has been established in 1994 as a spin-off from Bochum University, Germany.

The initial funding for setting up the institute has been provided by the Ministry for the Environment of the State of North-Rhine Westphalia, Germany's largest federal state.

However, IKT is not owned by the Government. Its owners are two associations which are again non-profit organizations of their own:

a) IKT-Association of Network Operators:
Members are about 100 cities, among them Berlin, Hamburg, Cologne and London (Thames Water). They hold together 66.6% of IKT.

b) IKT-Association of Industry and Service Providers: Members are about 60 companies. They hold together 33.3% of IKT.

You can find information on projects and services at:
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