Inspecting pressure sewer pipes: Potential, requirements and results

Pressure sewer pipes are well down a sewer operator's list of their favourite parts of the network. Because there are no inspection or maintenance ports. Because the precise location of the pipe is often not known. Because numerous bends obstruct the flow. They can be found in practically all drain and sewer networks, but their characteristics and their special design confront sewer network operators with a real challenge when it comes to inspection and condition surveying.

Legal provisions

Pressure sewer lines can be found in many sewer systems and are subject to the legal provisions concerning inspection and condition survey, as defined for example in German federal states' regulations for self-inspection and self-monitoring. Sewer network operators frequently find themselves facing special challenges in implementing the required inspection work. High points and low points with no valves complicate draining and venting. There is a danger of blockages of the gravity system if pump operation is interrupted, with the potential for back-ups and flooding.

Against this background, sewer network operators also report significant consequential risks, such as soil collapse, long-term operating restrictions, elevated operating costs and greater proneness to depositions within the pipe resulting in permanently reduced delivery volumes.

The first phase of an IKT research project "Inspection and condition-surveying of pressure sewer lines and culverts" found that life-cycle observation of pressure sewers is becoming ever more important. This research was commissioned by the environmental ministry of the German state of North Rhine-Westphalia and supported by a group of sewer network operators [1].

This article reports on key new knowledge gained during the second phase of this project, which was conducted by IKT jointly with more than twenty sewer network operators [2]. The main results provide sewer network operators and technology suppliers with better understanding of the requirements for inspection technologies, the performance of water tightness tests and the selection of rehabilitation methods for pressure sewer pipes. A qualitative risk model for prioritising pipe-specific inspection, which is already being used by operators, is also discussed.

Test deployments of inspection technologies

Wastewater pipes must be robust, stable, operationally reliable and watertight, and must remain so throughout their scheduled service-life. The development of suitable inspection methods must address these targets. Therefore, the existing technical options were first discussed in a workshop with manufacturers of inspection technologies for wastewater pipes and for other supply piping (oil, gas, water, industry, etc.). The issues examined included the civil-engineering boundary conditions, possibilities for pipe-jacking, the special requirements of standards and codes of practice, and the water-tightness test as an augmentation of the standard inspection.

The technology manufacturers and sewer network operators identified specific requirements for inspection technologies focusing on:

- Water-tightness
- Leak detection
- Detection of weak points (in the pipe wall)

Two inspection technologies were then investigated to determine the extent to which these

Manufacturers and sewer network operators discuss requirements for inspection technologies

requirements can be achieved. The majority of pressure sewer pipes consist of steel, cast iron, asbestos cement or plastic, and so the investigations concentrated on these pipe materials. The following inspection methods, which are suitable in principle for such materials, were used and the information they generated and their performance efficiency was analysed:

- Steel: sewer radar, eddy-current method (SloFec)
- Cast iron: eddy-current method (SloFec)
- Asbestos cement: sewer radar

Test measurements were performed on pipe samples and in-situ deployments of the inspection technologies were monitored and documented.

The use of sewer radar in asbestos-cement pipes proved to be highly promising in principle. The test results obtained were also confirmed by means of a pH test using phenolphthalein. Phenolphthalein was used in an IWW, Mülheim, research project, and initially served the purpose of control measurement. Wall-thickness losses and discontinuities in the material were detected by the sewer radar system.


In-situ deployment of sewer radar

The eddy-current method (SloFec) was used to determine the order of magnitude of defects/leaks in one steel and one cast-iron length of pipe. It proved possible to detect both sudden changes in wall thickness and flat-surfaced simulated points of corrosion attack in both steel and cast iron. For steel pipe, it was possible to


Eddy-current test (SloFec) in a pipe sample

determine with certainty both defect depths and their precise position within the pipe. In the case of cast iron, accurate location was possible, but defect depths of diameters of <6.5 mm were inadequately detected by the sensors used.

Water-tightness testing standards

The sewer radar and eddy-current method (SloFec) are, in principle, not suitable for use in plastic pipes. Consequently, hydraulic (water-pressure) tightness testing may be more appropriate for this type of conduit. In addition, water-tightness tests are included in the standard procedures required for on-site acceptance inspection of gravity and pressure wastewater pipes in accordance with DIN EN 1610 [3]. However, for pressure sewer pipes, this standard only draws attention to DIN EN 805, „Water Supply - Requirements for Systems and Components Outside Buildings" [4] or, in the 1997 edition, to the prEN 805 draft standard.

DIN 1671, „Pressure Sewerage Systems Outside Buildings" [5] also cites DIN EN 805 in conjunction with inspections prior to the commissioning of a pipeline. The inspection procedure outlined in DIN EN 805 is described in more detail in DVGW Code of Practice W 400-2, „Technical Rules for Water Distribution Systems (German: TRWV), Part 2: Construction and Inspection" [4]. There is, at present, no dedicated inspection procedure for existing buried pressure sewer lines.

Water-tightness testing in accordance with DIN EN 805 was found to constitute an very high labour and financial cost for the project's participating sewer network operators. Consequently, they could not provide any in-situ test sites during the course of the project. Therefore, a test pipe for water tightness tests was set up at IKT as an alternative.

Contractors

Four water-tightness testing contractors for the gravity and pressure sector were commissioned to perform testing on the test pipe. Their selection was based on market research (Internet, visits to trade fairs), with subsequent enquiries placed with more than ten companies who explicitly claimed to have capabilities in the field of tightness testing. The aims of this investigation were to comparatively determine whether:

- differences exist when testing is performed at differing pressures;
- test time plays any significant role;
- testing can be performed with air remaining in the pipe;
- water-tightness can be reliably determined by means of such a test;
- adaptation to the conditions encountered in pressure sewer lines is actually possible.

A 27 m long PE 100 SDR17 DN 150 nominal diameter pressure pipe was installed in IKT's outdoor site in an existing 30 m long sewer section of DN 2200 concrete pipes. The test pipe was constructed to simulate difficult geometric circumstances (bends, ascents, slopes) and designed in such a way that the high points and low points could be variably selected.

The four contractors each performed water tightness tests on the test pipe. However, IKT itself first conducted its own tests using the same test programme and its own measuring technology was used for this purpose. This focused on three configurations.

The first test started initially using Condition 1 in which an air pocket of 8.0% of the entire calculated capacity of 424.72 l was created in the bend in Section 2.

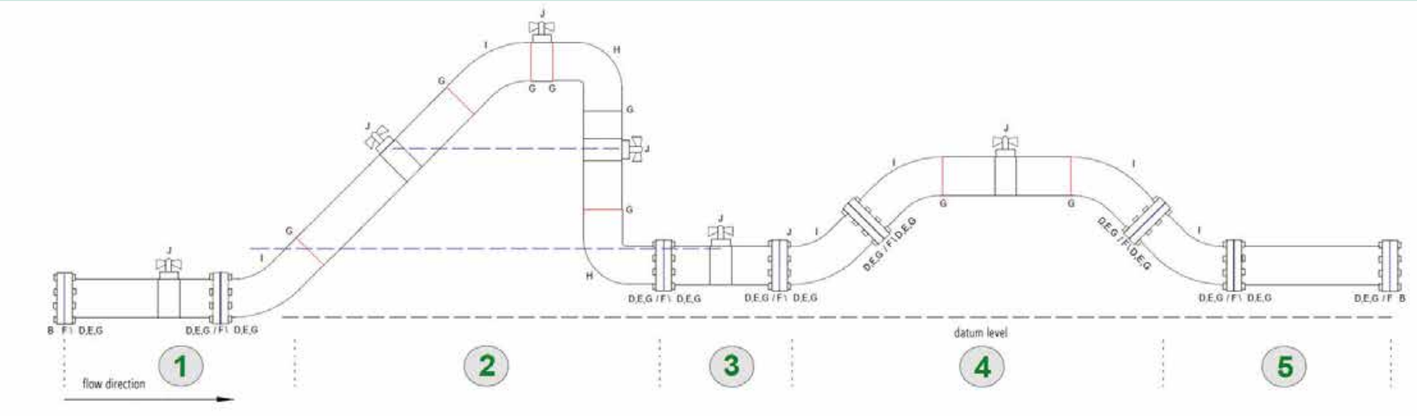
If no air was initially found in the test length by IKT or the contractor, the second test was conducted with an air pocket of 30.0% of total capacity (Condition 2).

Where the air pocket was found during the first test, the test length was completely filled with water in Condition 3 and then tested again.

Overall, the key questions were whether the contractors were aware of the individual process operations for water tightness testing and whether they were capable of applying them correctly. It was also intended to determine where there were any deficiencies and what limitations there were in performance.

Supplementary tests

IKT also performed supplementary tests on the sample pipe address other concerns expressed by the sewage network operators about water tightness tests on existing pipelines. In these the test criteria and boundary conditions were varied, and the results compared against one another. Questions on the extent to which limits can be determined and DIN EN 805/DVGW W



Test length of plastic pipe subdivided into sections with numbered valves

400, Part 2 test can be optimised, were also investigated. The following test criteria and test boundary conditions were selected:

- Water-tightness
- Magnitude and number of leaks (max. up to two leaks, each 55 µm)
- Variable test time (as per standard: 192 min.; 48 min.; 30 min.)
- Variable test pressures (8 bar; 6 bar; 5 bar; 4 bar))
- Air inclusions (no air; with 1.25% air; with 2.50% air)

The test time was the most important criterion for the sewer network operators. It is apparent, when examining the standards, that standard water-tightness tests can last for at least three hours. In fact, a test can take more than twelve hours in some cases, depending on the material. This long test period means that sewer network operators cannot easily interrupt operation for the necessary time. The consequence might be unacceptably large back-ups within the sewer system.

For this reason, a requirement was set that water-tightness tests should be completed within a relatively short time, in order to keep interruptions to operation to a minimum. Discussion with the sewer network operators concluded that 30 minutes was the target figure, signifying that the test time envisaged in DIN EN 805/DVGW W 400, Part 2 needed to be reduced to around a tenth of its original length.

The extensive tests performed demonstrated that it was possible to complete precise water-tightness tests in accordance with DIN EN 805 and DVGW W 400, Part 2 on IKT's test rig. The testing programme was able to investigate all of the test criteria and parameters selected to represent diverse situations in real sewer networks.

Knowledge gained

The detailed results of the investigations of water-tightness testing on pressure sewer lines are presented in greater detail in the concluding report for this research project [2]. The key conclusions can be summarised as follows:

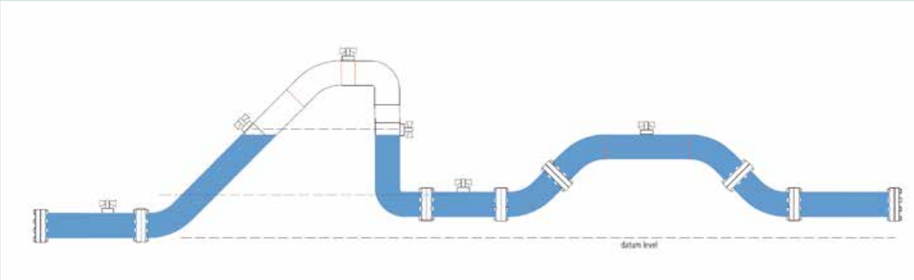
- It was ascertained during the tests performed by the contractors that three of the four contractors commissioned possessed inadequate knowledge concerning the performance of water-tightness tests on pressure sewer lines and concerning interpretation of the results.
- It was possible during the programme of testing to reduce the time needed for the performance of a water-tightness test to one tenth of the original requirement. The result nonetheless permitted assessment of the water tightness of the pipeline. However, the extent to which this can also be applied to other individual cases remains unknown at present.
- It is possible to identify leaks extremely quickly, assuming correct interpretation of the test results.
- Test pressure must not necessarily be greater than operating pressure in order to ascertain tightness. The tests showed that a conclusion concerning water-tightness can be drawn even at low pressure levels.

Qualitative risk management

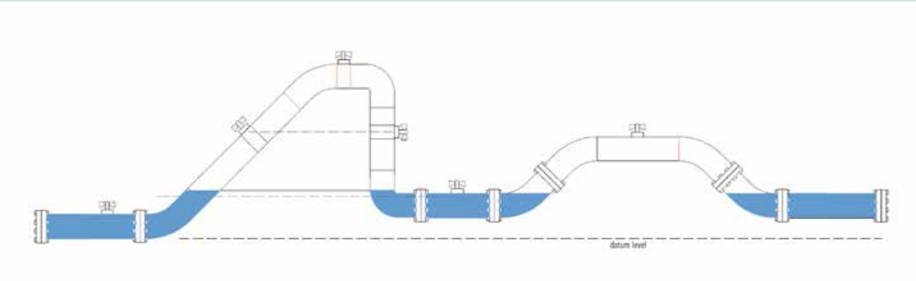
It is currently difficult to dependably assess installed pressure sewer pipes for their water-tightness, operational reliability and robustness, since inspections during operation are not usually considered at the design stage. Consequently, evaluation and management of the risk of failure confronts sewer network operators with significant challenges.

Therefore, IKT has developed a risk-analysis method for prioritising the most critical pipelines for a) possible further investigations and/or action, based on the probability of occurrence of failure, and b) for refurbishing of the pipeline based on the extent of damage. Thus, risks can be evaluated and controlled in such a way that the associated costs budgets can be systematically justified. A tried and proven procedure for this is risk evaluation of the probability of occurrence and the degree of damage involved, based on fixed evaluation data. Here, the same number of fixed risk values are assigned to both factors from which a risk index can be calculated, The significance of the relative values is shown in Table 1.

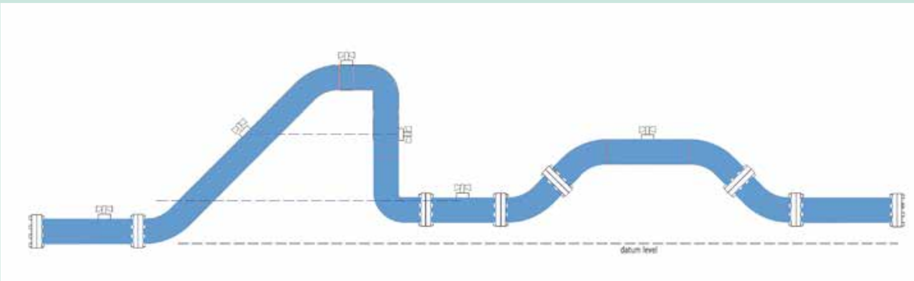
In an initial step, the possible risk factors for the respective operating network sector were determined and weighted (from 1 „Unimportant" to 5 „Extremely important") and the probabilities of occurrence of failure for each individual pipe were qualitatively estimated (again using a scale of 1 to 5 per risk factor) in a series of operator interviews conducted by means of questionnaires. The averages of the weighting of the risk



1. Bend in Section 2 half-filled with air



2. Bends in Section 2 and 4 filled with air



3. Test length completely bled and filled with water

Filling scenarios used in the test length of plastic pipe

A laptop records pressure data during water-tightness testing

Water-tightness testing equipment

IKT technology in use: a pressure sensor in the supply line

factors from all the questionnaires received are shown in Table 2.

In a normal case, several different approaches can be selected for determining extent of damage. For example, the extent of damage can be defined and determined in terms of its technical effects. The determination of technical rates of the extent of damage is generally extremely time consuming and is also not necessary undertaken in the context of a qualitative risk analysis.

Another possibility is determination of the extent of damage via economic factors. This was favoured by the participating sewer network operators, since the question of cost must be considered in all cases. Not only direct costs, but also indirect costs should be included in the analysis. The latter include costs which do not immediately affect the sewer network operator when a failure occurs. These include, for example, diversion of and safety provisions for traffic, the loss of road substance, damage to vegetation (lowering of the groundwater table, damage to roots) and also the additional burden on households/industry connected to the sewer, who must suffer restrictions for a period of time. These costs have, up to now, not been included in calculations, but nonetheless impose a long-term burden on the national economy [6].

Finally, and analogous to the remarks concerning risk criteria, criteria for describing the extent of damage were proposed and their weightings specified. This was undertaken by an internal discussion between the participating sewer network operators. Costs were in all cases considered to be the most important aspect by sewer network and were included in the evaluation with twice the importance (weighting: 2.0) of the other two criteria: the number of households/industrial enterprises connected and the environmental effects (weighting: 1.0 each). The sewer network operators that were consulted had the opportunity to definine/adjust the weighting at their own discretion (Table 3).

Once the individual weighting, the probability of occurrence and the extent of damage had been determined on the basis of the methods discussed above for all identified risks, they



PE 100 test rig, installed in 30 m long concrete pipe DN 2200

were entered in a risk portfolio. This is an instrument which provides an overview of the risk situation. Risk management was performed on this basis. The primary aim of risk management is that of achieving with the potential options available a „... reduction of the probability of occurrence (...) or a limitation of the effects of risks..." [7]. The drafting of a target risk portfolio is recommended, in order to assure the most efficient possible working procedure when assessing the Target/Actual condition.

Strategically important targets can be achieved for the pressure sewer network. A risk analysis of individual networks then permits classification of the various pressure lines within it. The network operator can decide at his or her own discretion which provisions, such as more extensive condition surveys or refurbishing projects, he or she wishes to deploy in order to reduce risk. Various classes of existing sewer can also be defined on the basis of the risk portfolio, enabling a network operator to manage the risks on a class basis. This risk model was implemented in cooperation with the municipalities of Burscheid, Bottrop and Gevelsberg.

Prospects

The inspection and condition-surveying of pressure sewer pipes continue to present special challenges to sewer network operators. The aim of this research project was to supply such operators with new knowledge concerning the operation and management of pressure sewer pipes. The focus was on the development of a risk model for pipeline-specific prioritisation of the need for action on inspection and refurbishing of critical pressure sewer lines. The risk evaluation enables sewer network operators to perform for themselves the assessment and management of existing risks.

The following areas were identified as requiring further work through optimisation or more extensive investigation:

- The available inspection technologies cannot, at present, be used for small-diameter pressure sewer pipes. Internal inspection of small pipes, which are found, in particular, in the private sector, is thus not yet possible.
- Among sewer network operators, there is in some cases lack of knowledge concerning the use of inspection methods. For this reason, sewer network operators should receive training, in order that they themselves, and also the private individuals advised by them (with respect to private pipes) are appropriately informed concerning the potential use of these inspection methods.

Table 1: Risk index for probability of failure and extent of damage observed

Risk index	Probability of occurrence	Extent of damage
1	Impossible[1]	Very low
2	Unlikely	Low
3	Possible	Moderate
4	Probable	High
5	Very probable	Very high

[1] This does not denote a scientific impossibility, but a qualitative abbreviation of the condition „in no way to be expected under normal conditions"

Table 2: Risk factors and weighting (averages of all questionnaires)

Risk factors	Weighting
Geometry/diameter of the pressure pipeline	2.57
Age of pressure pipeline	4.14
Location/depth of pressure pipeline	2.57
Installation/bedding errors	3.00
Technical pump aspects	3.29
Conveyed fluid	3.86
Materials properties	3.86
Soil properties	2.00

Table 3: Extent of damage factors and weightings

Damage-extent factors	Weighting
Costs	2.0
Number/importance of connected households	1.0
Environmental effects	1.0

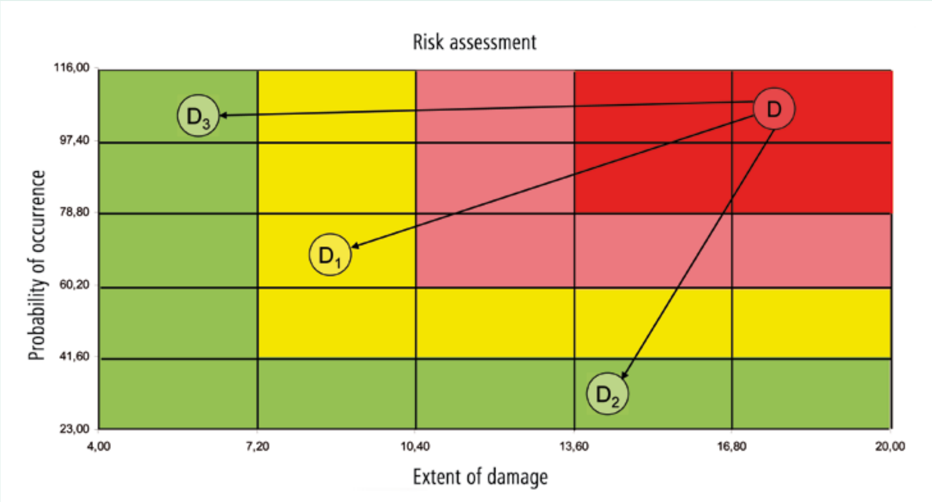
- Serious deficiencies were apparent in some cases in the performance of water-tightness tests by contractors. For this reason, sewer system operators and the contractors should be trained to improve their understanding of the results and in the correct performance of tightness tests on pressure sewer lines. Know-how in such fields as materials science/ building-materials technology, hydraulics, codes of practice, measuring technology and safety requires improvement.

- Shorter duration water tightness tests have the advantage that operation of a pipeline is interrupted only for a short time. For this reason, the development of shorter duration water tightness test should be investigated for other materials, such as steel, cast iron and concrete. Test sections should be constructed for this purpose, in order to evolve a procedure similar to that used for plastic pipelines. This would mean that water tightness tests would then be available for a major portion of existing pipes.
- Further investigations concerning risk analyses for existing pressure sewer lines are also necessary. In particular, the combination of prioritisation of the sewer pipes, lot formation and budgeting of further action is extremely important.
- Attention should also be devoted to sustainability aspects.

IKT workshop

The knowledge gained from this project has also been incorporated into the IKT „inspection, tightness testing and refurbishing of pressure sewer pipes" workshop. The workshop language is German.

- What are the important aspects for new sewer lines?
- How can testing of existing lines be performed?
- What is the right refurbishing procedure?



Target risk portfolio

The Authors

Dr.-Ing. Dipl.-Wirt.-Ing. Sissis Kamarianakis
Prof. Dr.-Ing. habil. Bert Bosseler
IKT – Institute for Underground Infrastructure

Literature

[1] Bosseler, B.; Harting, K.: Inspektion und Zustandserfassung von Abwasserdruckleitungen und -dükern, Phase I : Handlungsempfehlungen und technischen und wirtschaftlichen Aspekten, i. A. des Ministeriums für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen; Gelsenkirchen, Februar 2011.

[2] Kamarianakis, S., Lücke, A.: Inspektion und Zustandserfassung von Abwasserdruckleitungen und -dükern – Phase II, IKT – Institut für Unterirdische Infrastruktur, Gelsenkirchen, Dezember 2014

[3] DIN EN 1610: Verlegung und Prüfung von Abwasserleitungen und -kanälen, Beuth Verlag, Berlin, Oktober 1997.

[4] DVGW Arbeitsblatt W 400-2: Technische Regeln Wasserverteilungsanlagen (TRWV), Teil 2: Bau und Prüfung, Deutscher Verein des Gas- und Wasserfaches e.V., Bonn, September 2004.

[5] DIN EN 1671: Druckentwässerungssysteme außerhalb von Gebäuden. Beuth Verlag, Berlin, August 1997.

[6] Stein, D.: Instandhaltung von Kanalisation. Verlag Ernst & Sohn, 3. Auflage, Berlin 1999.

[7] Leibundgut, E.: Risk Management System – Risikofrüherkennung. In: Journal of security & risk information - Risk Times. Publikation 04, Monat 09, Jahr 2011.

neutral
independent
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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 more than 130 cities, among them Berlin, Hamburg, Cologne and London (Thames Water). They hold together 66.6% of IKT.

b) IKT-Association of Industry and Service:
Members are more than 70 companies. They hold together 33.3% of IKT.

You can find information on projects and services at:
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IKT – Institute for Underground Infrastructure

Exterbruch 1
45886 Gelsenkirchen
Germany

phone: +49 209 178060
fax: +49 209 17806-88
email: info@ikt.de

IKT is located
ca. 30 min. off Düsseldorf
International Airport.

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