Mosbaek CEV flow regulator

Verification Report

Verification Report
February 2015

This report has been prepared under the DHI Business Management System
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QUALITY SYSTEM CERTIFICATION

DNV·GL

ISO 9001

DNV GL BUSINESS ASSURANCE DENMARK A/S

Approved by Sten Lindberg (Head of department, DHI)

Approved by Peter Fritzel (Verification responsible, ETA Danmark)

Mosbaek CEV flow regulator

Verification Report

Prepared for **Mosbaek A/S**
Represented by **Torben Krejberg, Technical Director**

Test facility

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Contents

Figures

Tables

Appendices

Archiving: All standard project files (documents, etc) are archived at ETA Danmark. Any other project files (set-up files, forcing data, model output, etc.) are archived with the institute performing the tests or analysis.

1 Introduction

Environmental technology verification (ETV) is an independent (third party) assessment of the performance of a technology or a product for a specified application under defined conditions and quality assurance.

The objective of this verification is to evaluate the performance of a vertical centrifugal flow regulator for storm water.

This Verification Report and the verification of the technology are based on the Specific Verification Protocol, Test Plan and Test Report for the Mosbaek CEV flow regulator, included as Appendix B, D and E.

1.1 Name of technology

Vertical centrifugal flow regulator, CEV (**CE**ntrifugal **V**ertical), produced by Mosbaek A/S.

Mosbaek produces CEVs for flow capacities from 0.2 l/s to 80 l/s. The verification will cover verification test of four specific CEV dimensions within this range.

Mosbaek have selected four specific CEV-models to represent their CEV technology, namely:

- CEV 1.4l/s @ 1.00m – 100%
- CEV 4.9l/s @ 1.50m – 100%
- CEV 10.5/s @ 2.00m – 78%
- CEV 10.5l/s @ 2.00m – 100%

The name of the CEV indicates the designed maximum flow of for example 1.4 l/s and the correlating maximum pressure height of for example 1.00 m. The percentage (100% and 78%) indicates the percentage of the design flow at the point/bump where the vortex is formed.

1.2 Name and contact of proposer

Mosbaek A/S
Værkstedsvej 20
4600 Køge
Denmark

Contact: Torben Krejberg, e-mail: tk@mosbaek.dk, phone: +45 5663 8580

Mosbaek website: www.mosbaek.dk

1.3 Name of verification body and responsible of verification

ETA Danmark A/S
Göteborg Plads 1
2150 Nordhavn
Denmark

Verification responsible:
Peter Fritzel (PF), email: pf@etadanmark.dk, phone +45 7224 5900

Appointed verification expert:
Mette Tjener Andersson (MTA), e-mail: mta@dhigroup.com, phone: +45 4516 9148

1.4 Verification organisation including experts

The verification was conducted by ETA Danmark A/S in cooperation with Danish Centre for Verification of Climate and Environmental Technologies, DANETV, which performs independent verification of technologies and products for the reduction of climate changes and pollution.

The verification is conducted to satisfy the requirements of the ETV scheme established by the European Union (EU ETV Pilot Programme) [1].

The verification was coordinated and supervised by ETA Danmark, assisted by an appointed verification expert, while tests were coordinated and supervised by DHI with the participation of the proposer, Mosbaek. The testing was conducted at the premises of Mosbaek in Køge, where a test facility has been constructed.

An internal and an external expert are assigned to provide independent expert review of the planning, conducting and reporting of the verification and tests:

- Internal technical expert: Morten Just Kjølby (MJK), DHI, Urban and Industry Dept., e-mail mjk@dhigroup.com
- External technical expert: Verification protocol: Professor Torben Larsen (TL), Aalborg University, Department of Civil Engineering, e-mail tl@civil.aau.dk. Verification Report: Ian Walker (IW), WRc plc, e-mail Ian.Walker@wrcplc.co.uk

The tasks assigned to each expert are given in more detail in section 4 Quality assurance.

The relationships between the organisations related to this verification and test are given in Figure 1-1.

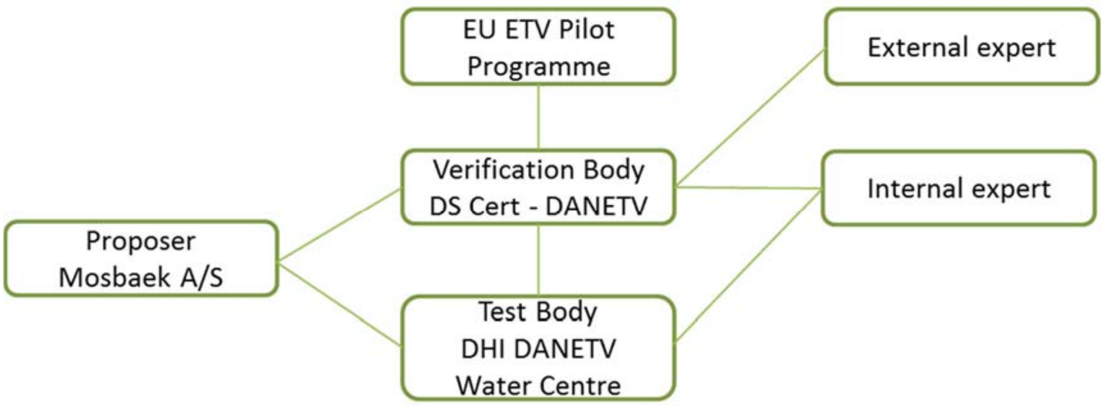

Figure 1-1 Organisation of the verification and test.

1.5 Verification process

The principles of operation of the DANETV verification process are given in Table 1-1

Table 1-1. As it can be seen, verification and testing are divided between the verification and the test body.

Table 1-1 Simplified overview of the verification process.

Phase	Responsible	Document
Preliminary phase	Verification body	Quick Scan
		Contract
		Specific verification protocol
Testing phase	Test body	Test plan
		Test report
Assessment phase	Verification body	Verification report
		Statement of Verification

Quality assurance is carried out by an expert group of internal and external technical experts. Two audits of the test system were performed, starting with an internal audit by the test body followed by an external audit by the DANETV verification body under ETA Danmark. Reference for the verification process is the EU ETV General Verification Protocol [1] and ETA Danmarks internal procedure [2]. A Statement of Verification will be issued by ETA Danmark after completion of the verification. This verification report will include the other documents prepared as appendices.

1.6 Deviations from the verification protocol

There were no deviations to the verification protocol.

2 Description of technology and application

2.1 Summary description

The flow regulator technology for extreme rainfall events is based on quickly reaching the maximum discharge flow and staying at or below this value. The maximum discharge flow is the allowable amount of water passing through the regulator without causing any problems to the downstream pipe network.

The technology verified is the vertical centrifugal flow regulator, CEV (**CE**ntrifugal **V**ertical) from Mosbaek. It is a wet mounted vortex flow regulator for storm water with design flows between 0.2 and 80 l/s.

The CEV regulates the water due to the vortex created when sufficient water flow is going through the unit. The vortex is created when the water flow reaches a certain flow rate. The vortex slows down the water flow through the CEV. In this way the water is stored in the well and the water flow is then kept almost constant. A schematic view of the CEV in operation is shown in Figure 2-1.

The CEV can be designed to fulfil different design criteria. The specific design criteria are defined by the client and Mosbaek in cooperation according to the design of the existing or planned piping network.

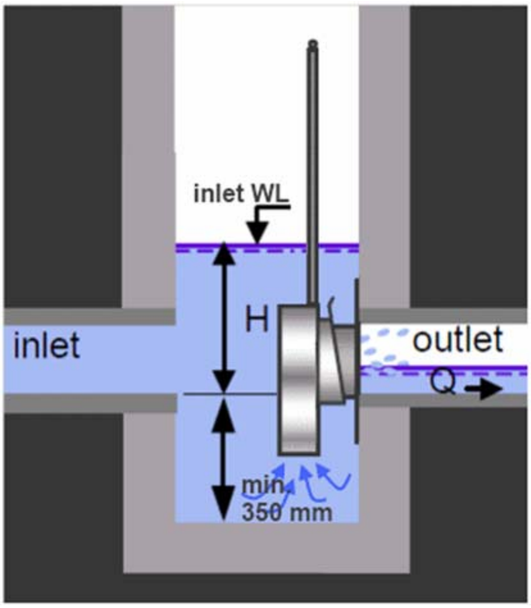

Figure 2-1 Sketch of CEV flow regulator installed in well. Sketch provided by Mosbaek.

The CEVs verified have inflow in the bottom of the regulator, as shown in Figure 2-1. This is to ensure proper and equal hydraulic conditions. Furthermore, in a standard installation Mosbaek will ensure that inlet and outlet are located at the same level in the well (as depicted on Figure 2-1) in order to be able to control the water level rise in the well optimally.

Figure 2-2 shows the flow through a CEV. In the 100% case the maximum outlet (Q_{design}) is met twice - first where the vortex is formed (the bump on the graph) and then at the specified H_{design}, where H_{design} is calculated from the invert of the discharge pipe to the maximum water level in the well. A 78% case (a smaller CEV in a well with same height) with the same H_{design} is also shown; here the bump occurs at a flow of 78% of Q_{design}.

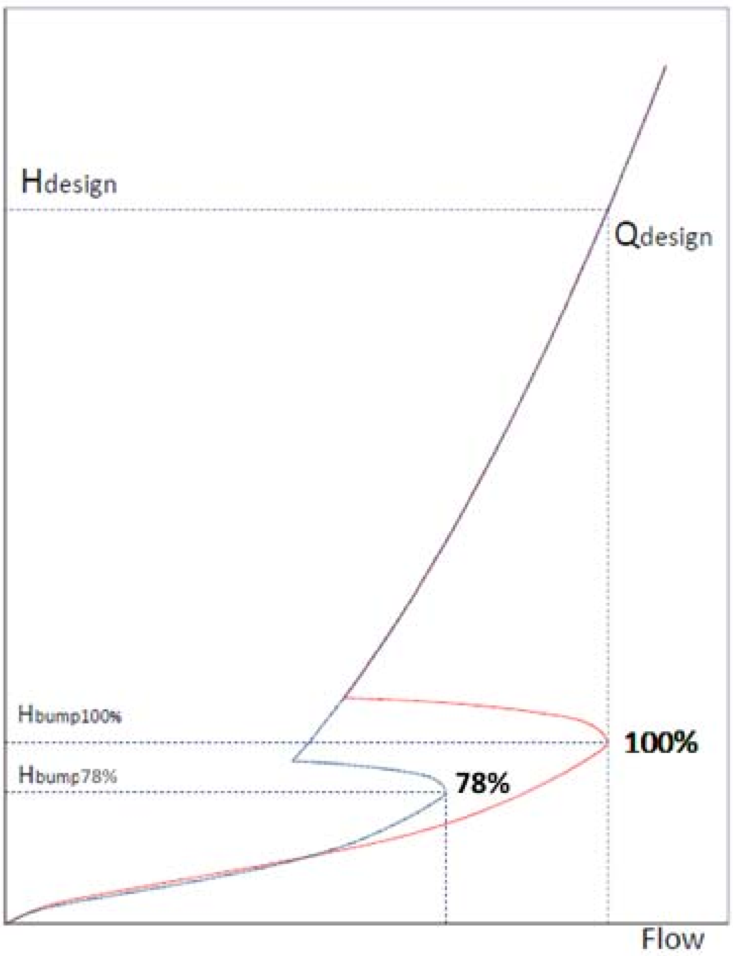

Figure 2-2 Graphic showing the general vortex brake effect on water outflow, with CEVs operating at 78% and 100% efficiency and water inflow to well larger than outflow though CEV (well is filling up). Graph provided by Mosbaek.

The optimal solution (100%), where Q_{bump} equals Q_{design}, gives less restriction at low heads allowing a better flow during normal operating situations and thereby less risk of blocking downstream.

2.2 Intended application

The intended application of the technology for verification is defined in terms of the matrix and the purpose.

2.2.1 Matrix/matrices

The CEV is for storm water and certain types of industrial wastewaters. The CEV is installed before the combined system (with storm water and wastewater), and is thereby restricting the amount of storm water into the combined system. The verification therefore only covers the matrix storm water.

2.2.2 Purpose(s)

The purpose of the technology is to store storm water at appropriate places before entering the piping system during storm water events. The CEV is installed in wells and basins depending on the piping network.

2.3 Verification parameters definition

There is no regulation to fulfil for this technology. The initial claims from the proposer are matching the claims from other vendors. No need has been found to add any additional performance parameters to those initially selected by the proposer.

Mosbaek has two types of claims for their CEVs, both described below.

2.3.1 Flow at H_{bump} and H_{design}

Mosbaek has specified the performance of four selected models of the CEV through performance graphs and specified the following specific claims (for details, please consult Appendix B):

100% model: **Q_{design} ±5% is met at H_{bump} and H_{design}**

X% model: **X% of Q_{design} ±5% is met at H_{bump}**
Q_{design} ±5% is met at H_{design}

Specific values for each of the four selected CEVs are listed in Table 2-1.

Table 2-1 Specific performance claims from the proposer on Q_{bump} and Q_{design}.

CEV model	Q_{bump} (l/s)	Q_{design} (l/s)
CEV 1.4l/s @ 1.00m – 100%	1.4 ±5%	1.4 ±5%
CEV 4.9l/s @ 1.50 m – 100%	4.9 ±5%	4.9 ±5%
CEV 10.5l/s @ 2.00m – 78%	8.2 ±5%	10.5 ±5%
CEV 10.5l/s @ 2.00m – 100%	10.5 ±5%	10.5 ±5%

2.3.2 Flow reduction at H_{design}

Mosbaek has further specified their claimed reduction of the flow at H_{design} compared to a well with no flow regulator (equal to a hole in a straight wall, with no additional piping).

Mosbaek claims the following:

A Mosbaek CEV 100% model can reduce the flow by a factor of 4.25 at Q_{design}

Performing tests where the test well is filled up to H_{design} with no CEV will require very high water flow. Therefor this claim will be verified using only the smallest of the four CEVs used in the tests. Specific performance claim is listed in Table 2-2.

Table 2-2 Specific performance claims by the proposer on flow reduction compared to no CEV installed in well.

CEV model	Orifice diameter (Ø) (mm)	Flow reduction factor at H_{design}
CEV 1.4l/s @ 1.00m – 100%	Diameter corresponding to CEV 1.4l/s @ 1.00m – 100% outlet	4.25

3 Evaluation

Detailed descriptions of the test design and test results are found in the Test Plan (Appendix C) and Test Report (Appendix D).

3.1 Calculation of verification parameters performance

Detailed information on how to calculate the verification parameters are included in the Specific Verification Protocol in Appendix B.

3.2 Evaluation of test quality

3.2.1 Control data

Test system control included leakage test and for CEV1.4l/s @ H=1.00m – 100% investigation of the variation was included for tests carried out with identical inlet flows. The variation was minimal and far less than 10 %, which means - according to the Verification Protocol (Appendix B), section 5.1.4 - that triplicate tests were not needed for the remaining CEVs.

Test performance audit included review of calibration certificates for pressure transducers and flowmeters. They are valid and can be found in Appendix to the Test Plan (Appendix C). In addition calibration tests were performed of pressure transducers on both inlet and outlet side.

The outflow could not be measured directly due to air and circulation in the outlet. Instead measurement of head in the outlet tank and of the overflow from the outlet tank where measured. The calculation two different methods were listed , see Appendix B section 6.1 Calculation of performance parameters. Method 2 was expected to most precise, while method should be used for control. For method 1the time series had to be subjected to intensive averaging to get readable results. A comparison between the results obtained by means of method 1 and method 2 for one of the model tests has been performed. The results are shown in the Appendix D of the Test Report (Appendix D to this report). It appears that there is, apart from the fluctuations, a good agreement between the two methods. However, since the quality of the results with method 2 was very reliable and, while the results obtained by means of method 1 are subject to large fluctuations, it was chosen to use method 2 only.

3.2.2 Audits

During testing and internal test, a system audit was performed by Jesper Fuchs from DHI on 29 September 2014. The verification body ETA Denmark, represented by Peter Fritzel, performed a test system audit on 2 October 2014.

Conclusions of the internal audit (Jesper Fuchs):

“The test is performed in accordance with the test plan and carried out in a safe manner. Handling and storage of data is safe”.

Conclusions of the audit by ETA Denmark (Peter Fritzel):

“There is consistency with the test plan and handling of measurements is carried out in a safe manner”.

The full audit reports can be found in Appendix E.

3.2.3 Deviations

There were four deviations to the test plan. The description of these can be found in full in Appendix C of the Test Report included as Appendix E to this report. A summary of the deviations is as follows:

1. Instead of establishing the zero level in the inlet tank for each test, a common zero scan was performed for each CEV type. This zero scan was carried out as an individual test instead of an integrated part of each test.

2. The lowest inflow in the tests with CEV 1.4l/s @ 1.0m was carried out with too low inflow, 1.79l/s instead of 1.9l/s. With good accuracy the inlet flow, which will result in a water level rise of 0.5mm/s, can be found by interpolation. Such interpolation shows that an inflow of approximately 2.8l/s will result in a water level rise of 0.5mm/s. The corresponding Qbump would be approximately 1.28l/s (see Figure 3.8 in Test Report (Appendix E)).

3. For all 100% CEVs the largest inflows gave larger water level rise than 1.5mm/s, which was the largest water level rise to be tested and a predefined operational parameter. During the test attempt was made to come close to 1.5 mm/s, but due to the character of the curve, with the rapid bump, it was difficult in advance to estimate the water level rise. With good accuracy the inlet flows, which will result in a water level rise of 1.5mm/s, can be found by interpolation. Doing this is it nice to have a measured values of water level rise is above 1.5 mm/s. Interpolations show for:

    - CEV 1.4l/s @ 1.0m that such a water level rise would be obtained for an inflow of approximately 6.1l/s. The corresponding Qbump would be approximately 1.44l/s (see Figure 3.8 in the Test Report (Appendix E))

    - CEV 4.9l/s @ 1.5m that such a water level rise would be obtained for an inflow of approximately 9.2l/s. The corresponding Qbump would be approximately 4.93l/s (see Figure 3.12 in Test Report (Appendix E))

    - CEV 10.5l/s @ 2.0m that such a water level rise would be obtained for an inflow of approximately 13.9l/s. The corresponding Qbump would be approximately 10.4l/s (see Figure 3.16 in Test Report (Appendix E))

4. The test with the orifice was carried out with a larger inflow than predefined. This was done, as the Q – H relation for an orifice is independent of the water level increase, which also is documented by comparing with the theoretical relation, see Figure 3.23 in the Test Report (Appendix E).

3.3 Verification results

3.3.1 Performance parameters

The verified performance for the two parameters is listed below. The results are transferred directly from the Test Report (Appendix E).

3.3.2 Flow at H_{bump} and H_{design}

Specific performance for each of the four selected CEVs is listed in Table 3-1 and Table 3-2.

Table 3-1 Verified performance on Q_{bump}. +) Be aware that the results of Q_{bump} are uniquely influenced by Q_{inflow}, see later.*) For this flow the water level rise was only 0.19 mm/s, while the operational requirement was >0.5 mm/s, this is an explanation for the deviation from the expected.

CEV model	Inflow in test (l/s)	Q_{bump} (l/s)	Deviation from model characteristics (%)

		Mean+	Range	
CEV 1.4l/s @ 1.00m – 100%	1.79 to 6.31	1.34	1.22* – 1.45	-4.3 (-13* – 3.6)
CEV 4.9l/s @ 1.50 m – 100%	5.89 to 9.99	4.74	4.50 – 5.04	-3.3 (-8.2 – 2.9)
CEV 10.5l/s @ 2.00m – 78%	8.60 to 12.97	8.17	7.57 – 8.74	-0.2 (-7.6 – 6.7)
CEV 10.5l/s @ 2.00m – 100%	11.32 to 15.24	10.18	9.75 – 10.67	-3.0 (-7.1 – 1.6)

Table 3-2 Verified performance on Q_{design}. *) based on two tests only.

CEV model	Inflow in test (l/s)	Q_{design} (l/s)		Deviation from model characteristics (%)
		Mean	Range	
CEV 1.4l/s @ 1.00m – 100%	1.79 to 6.31	1.43	1.42 – 1.45	2.1 (1.4 – 3.6)
CEV 4.9l/s @ 1.50 m – 100%	5.89 to 9.99	4.78	4-76 – 4.80	-2.4 (-2.9 – (-2.0))
CEV 10.5l/s @ 2.00m – 78%	8.60 to 12.97	10.11	10.09 – 10.12*	-3.7 (-3.9 – (-3.6))
CEV 10.5l/s @ 2.00m – 100%	11.32 to 15.24	10.56	10.55 – 10.56	0.6 (0.5 – 0.6)
Orifice	13.72	6.36	N/A	N/A

Please be aware that there is a unique influence of Q_{bumb} by Q_{inflow}, see Figure 3-1.

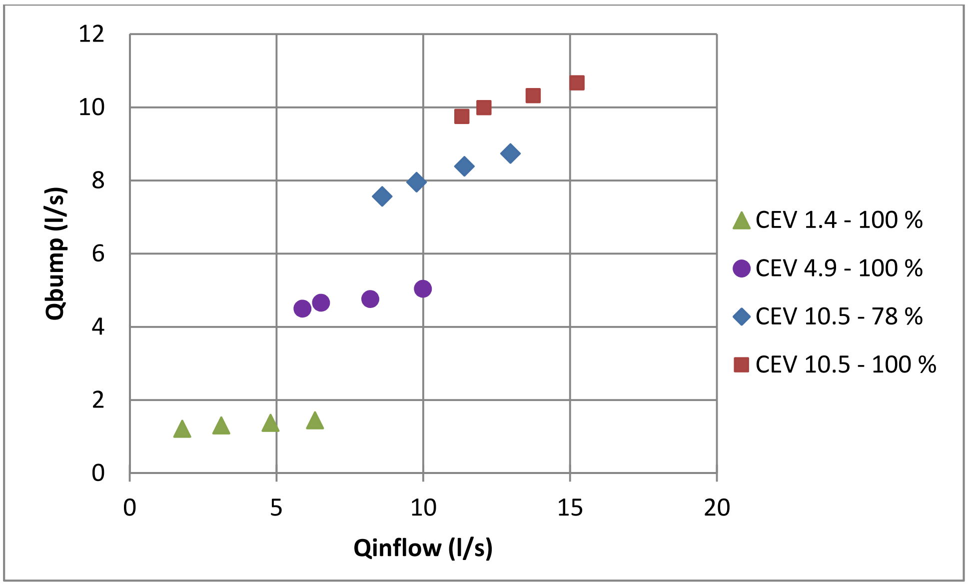

Figure 3-1 Correlation between Q_{inflow} and Q_{bump} given for all tested CEVs.

3.3.3 Flow reduction at H_{design}

Performance compared to a well with no flow regulator is listed in Table 3-3.

Table 3-3 Verified performance on flow reduction compared to no CEV installed in well.

CEV model	Orifice diameter (Ø) (mm)	Flow reduction factor at H_{design}
CEV 1.4l/s @ 1.00m – 100%	Diameter corresponding to CEV 1.4l/s @ 1.00m – 100% outlet	4.45

Mosbaek CEV 1.4l/s@1.00m - 100 % is verified to reduce the flow by a factor of 4.45 at Q_{design}.

3.3.4 Operational parameters

During operation the following parameters were measured:

- Inflow (l/s)
- Water level/pressure in regulator well (mH_2O/Pa)
- Water level/pressure in the outlet tank (mH_2O/Pa)
- Outlet from the outlet tank (l/s)

These data have created curves shown in the Test Report, section 3 Test results (Appendix E).

During the test the average water level must be within 0.5 and 1.5mm/s, since this is common values in runoff systems.

3.3.5 Additional parameters

3.3.5.1 User manual

The verification criterion for the user manual is that the manual describes the use of the equipment adequately and is understandable for the typical test coordinator and test technician. This criterion was based on a number of specific points of importance, see Table 3-4 for the parameters to be included.

A description is complete if all essential steps are described, if they are illustrated by a figure or a photo, where relevant, and if the descriptions are understandable without reference to other guidance.

Mosbaek has provided:

- Centrifugal valve CE/V wet mounted (General information)
- Installation Instruction. Mosbaek Flow Regulators. Type CEV-KPS – Sealing
- Maintenance and Inspection Instructions. Mosbaek Flow Regulators. Type CEV-KPS – Sealing

Table 3-4 Evaluation of user manual.

Parameter	Complete description	Summary description	No description	Not relevant
Product				
Principle of operation		√		
Intended use		√		
Performance expected	√			
Limitations		√		
Preparations				
Unpacking			√	
Transport			√	
Assembly	√			
Installation	√			
Function test	√			
Operation				
Steps of operation		√		
Points of caution		√		
Accessories		√		
Maintenance	√			
Trouble shooting		√		
Safety				
Chemicals				√
Power				√

3.3.5.2 Required resources

The capital investment and the resources for operation and maintenance could be seen as the sustainability of the product and will be itemized based upon a determined design [3], see Table 3-5for the items that will be included.

The design basis consists of one installed CEV in an existing well. All cost items relevant for the Mosbaek CEVs are listed. Note that the actual cost for each item is not compiled and reported.

Table 3-5 List of capital cost items and operation and maintenance cost items per product unit.

Item type	Item	Number/duration
Capital		
Site preparation	None	
Buildings and land	None	
Equipment	The CEV and mounting from Mosbaek Tightening material and bolts	1
Utility connections	Rain water sewer system and wells	1
Installation	To be installed by sewer contractor	1 day
Start up/training		
Permits	None	
Operation and maintenance		
Materials, including chemicals	None	
Utilities, including water and energy	None	
Labor	Regular inspection and drainage of sump/sand catcher	1 day
Waste management	Sump/sand	As for other wells with no CEV
Permit compliance	None	

Evaluation of the following subjects has been performed based on information gained from Mosbaek:

- *Resources used during production of the equipment in the technology*

  The CEV and their mounting are produced from stainless steel, grade 1.4404/316L.

  For the tested products incl. mounting the weights are:

  CEV 1.4l/s@1.0m 100% : 5.9 kg

  CEV 4.9l/s@1.5m 100%: 11.5kg

  CEV 10.5l/s@2.0m 78%: 21.5kg

  CEV 10.5l/s@2.0m 100%: 25.1kg

  80% of the steel on the world market is reused material. The main part of the steel in Denmark is imported from other European countries, while the rest is mainly from Taiwan, India and China. Depending on the distance the freight is by ship or by truck. For the European marked the transport is mainly by truck. Mosbaek purchases steel from Danish distributors such as: Dacapo Stainless, Lemvigh-Müller, Sanistål and Dam-stahl.

  The average energy consumption for the final product is 4.1kWh/kg.

- *Longevity of the equipment*

  The regulators are designed to last as long as the other components in a sewage system, approx. 50 years. A regulator will not need to be replaced unless inspection shows considerable wear and tear.

- *Robustness/vulnerability to changing conditions of use or maintenance*

  The regulator is robust to changes in temperature and environment. A steeper slope on the characteristic curve gives robustness towards changes in pressure head. Larger orifice opening, compared to other competing solutions, give robustness with respect to clogging. Maintenance scheme should be adjusted according to changes in condition concerning the quality of the water. Maintenance is a visual check of the condition of the regulator and to remove signs of clogging.

- *Reusability, recyclability (fully or partly) and end of life decommissioning and disposal*

  A regulator can be reused in another location with similar conditions or adjusted to fit other conditions. If reuse is not possible, the regulator can be sold as scrap and molten into new steel. It is 100% is recyclable.

3.3.5.3 Occupational health and environmental impact

The risks for occupational health and for the environment associated with the use of the products will be identified. A list of chemicals classified as toxic (T) or very toxic (Tx) for human health and/or environmentally hazardous (N) (in accordance with the directive on classification of dangerous substances [4]) will be compiled. The tightening material used for installation is chosen by the sewer contractor. The mainly used material is sealant tape or waterproof silicone, which are both unclassified.

All operations in wells are subject to safety risk, and standard safety precautions have to be taken accordingly.

3.4 Recommendation for the Statement of Verification

3.4.1 Technology description

The technology verified is the vertical centrifugal flow regulator, CEV (**CE**ntrifugal **V**ertical) from Mosbaek. The flow regulator technology for extreme rainfall events is based on quickly reaching the maximum discharge flow, where it creates a vortex making it stay at or below this discharge flow while the remaining water is stored in the well. A schematic view of the CEV with inflow in the bottom is shown in Figure 3-2a.

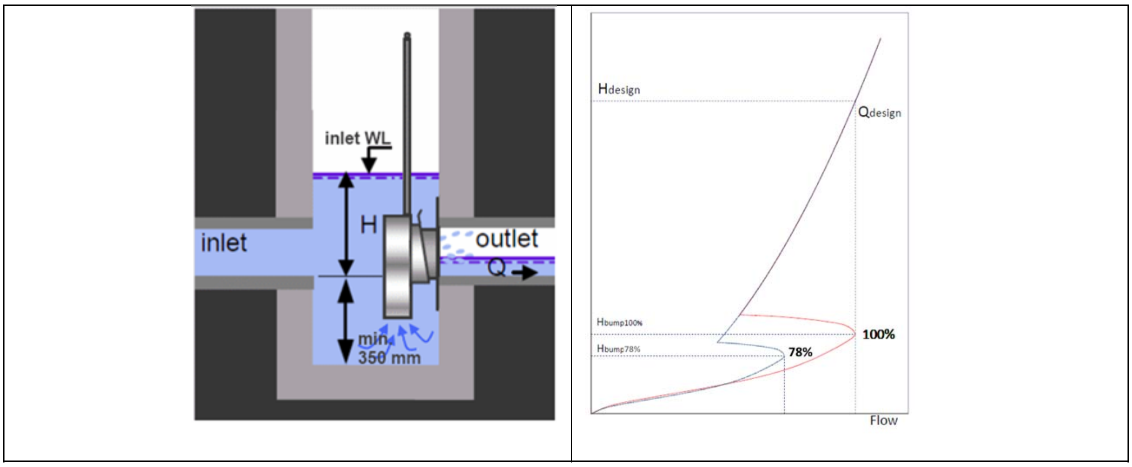

Figure 3-2 A) Sketch of CEV flow regulator installed in well. B) Graphic showing the general vortex brake effect on water outflow, with CEVs operating at 78% and 100% efficiency and water inflow to well larger than outflow though CEV (well is filling up). Both provided by Mosbaek.

Figure 3-2b shows the flow through a CEV. With a 100% model, the maximum outlet (Q_{design}) is met twice, first where the vortex is formed (the bump on the graph) and then at the specified H_{design}, where H_{design} is calculated from the invert of the discharge pipe to the maximum water level in the well. A 78% model is also shown; here the bump occurs at a flow of 78% of Q_{design}.

Mosbaek has selected four models to represent their CEV-series. The models are;

- CEV 1.4l/s @ 1.00m – 100%
- CEV 4.9l/s @ 1.50 m – 100%
- CEV 10.5l/s @ 2.00m – 78%

- CEV 10.5l/s @ 2.00m – 100%

3.4.2 Application

3.4.2.1 Matrix

The CEV is installed before the combined system (with storm water and wastewater) and is restricting storm water inflow to the combined system. The verification covers storm water.

3.4.2.2 Purpose

The purpose of the technology is to store storm water at appropriate places before entering the piping system during storm water events. The CEV is installed in wells and basins depending on the piping network.

3.4.2.3 Conditions of operation and use

Maintenance is needed regularly as a visual check of the condition of the regulator and to remove signs of clogging.

3.4.2.4 Verification parameters definition summary

Two types of parameters have been verified:

1. Outflow (l/s) at H_{bump} and H_{design}
2. Flow reduction at H_{design}

3.4.3 Test and analysis design

The test was designed for this verification. No existing data have been included.

3.4.3.1 Laboratory or field conditions

The test was performed at a test set-up at Mosbaek's premises in Koege, Denmark, see Figure 3-3.

The figure is suggested to be an appendix to the Statement of Verification.

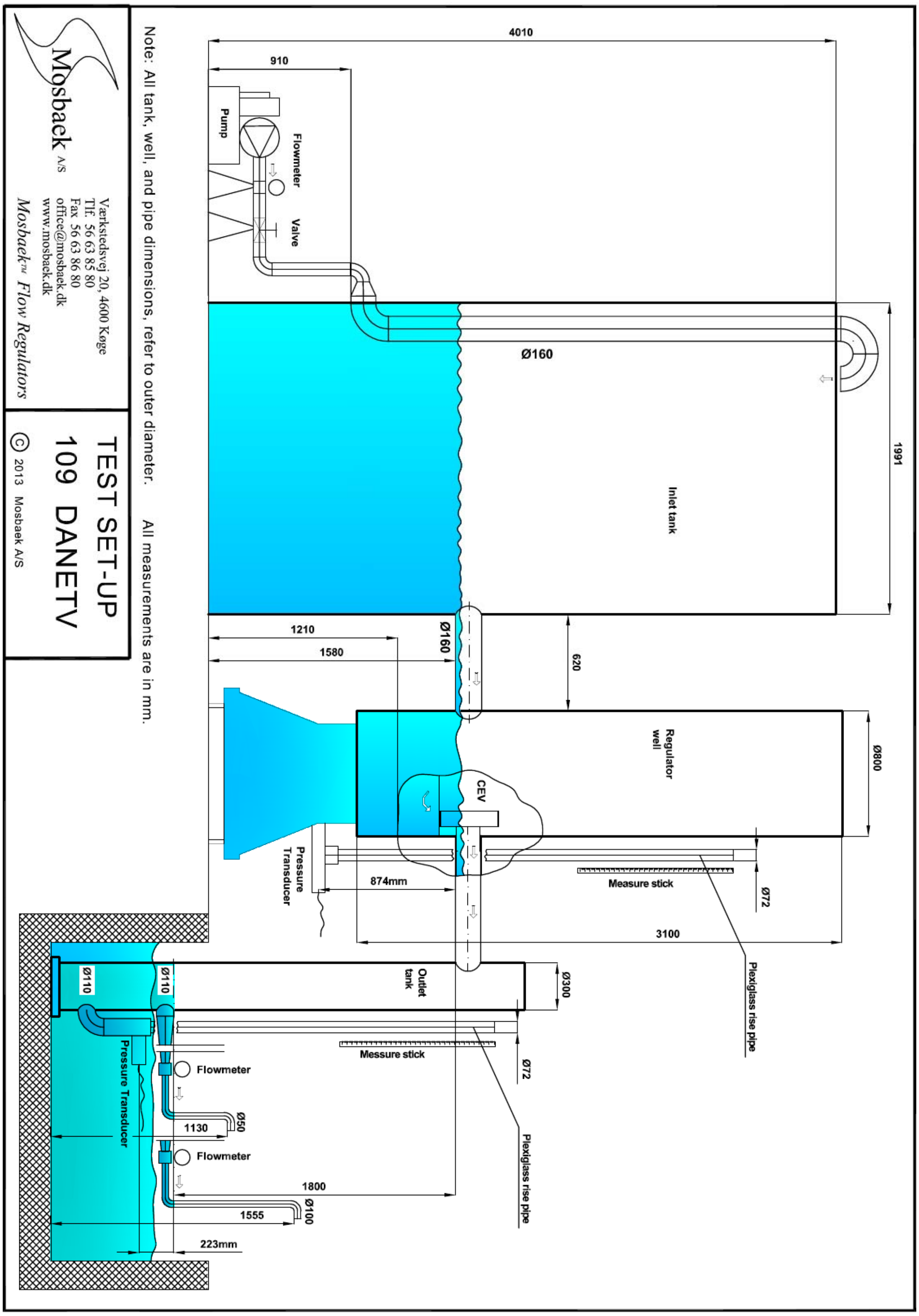

Figure 3-3 Sketch of test set-up.

The set-up consists of a well (regulator well) placed on a base; the CEV regulator is mounted in this well. The regulator well is in direct connection with a large diameter tank (inlet tank), through a pipe, positioned just opposite the CEV outlet. The water levels in the regulator well and the inlet tank are accordingly identical. This set-up is established in order to secure that the increase of the water level in the regulator well can be controlled and limited still with a reasonable high flow rate to the well. The outlet connection goes through the CEV in the regulator well to the outlet tank. A pressure transducer is mounted in the base of the regulator well. On the base of the regulator well, a Plexiglas riser is mounted in order to follow the water level in the well during testing.

The flow to the inlet tank is fed at the top of the tank through a pipe placed internally in the tank by means of a pump, which is pumping water from a feeding tank. The flow from the feeding tank to the inlet tank is measured by means of the flowmeter. The water level in the feeding tank is kept constant by pumping water from a central reservoir to the feeding tank; an overflow weir ensures that the water level in this tank is kept almost constant. In this way, it is possible to keep an almost constant pressure head at the pump and thus an almost constant flow.

From the regulator well, the water flows through the CEV to the outlet tank. The outlet tank has a pressure transducer monitoring the water level in this tank. The outlet flow from the outlet tank is measured by means of a flowmeter.

3.4.3.2 Matrix composition

The used water is from an outdoor reservoir.

3.4.3.3 Test and analysis parameters

The following test-runs were performed.

CEV model	Flow 1	Flow 2	Flow 3	Flow 4	Flow 4'	Flow 4''
CEV 1.4l/s @ 1.00m – 100%	1.79	3.12	4.80	6.31	6.18	6.25
CEV 4.9l/s @ 1.50 m – 100%	5.89	6.52	8.20	9.99		
CEV 10.5l/s @ 2.00m – 78%	8.60	9.77	11.40	12.97		
CEV 10.5l/s @ 2.00m – 100%	11.32	12.07	13.75	15.24		
Orifice	13.72					

Tests of the performance at H_{bump} and H_{design} are marked in light orange.

Test of the flow reduction at H_{design} is done by comparing the results from the hatched test runs.

The repetition of CEV 1.4l/s @ 1.00m – 100% (dark blue marking) is done to see if there is more than 10 % variation between runs with the same flow. There was very limited variation; therefore the repetition was not done for other test runs.

3.4.3.4 Test and analysis methods summary

The inflow and outflow from the CEV was measured by the use of flowmeters and pressure transducers as described above.

3.4.3.5 Parameters measured

- Inflow (l/s)
- Water level/pressure in regulator well (mH_2O/Pa)
- Water level/pressure in the outlet tank (mH_2O/Pa)
- Outlet from the outlet tank (l/s)

Outflow from CEV is calculated by using the following equation:

$$Q_{outflow} = Q_{overflow} + \frac{\Delta Hout \times Aout \times 1000}{\Delta t}$$

$Q_{outflow}$: Flow out of CEV (l/s)
$Q_{overflow}$: Overflow from the outlet tank (l/s)
A_{out}: Surface area in the outlet tank+riser (m^2)
H_{out} : Pressure head in the outlet tank (mH_2O)
Δt: Time for changing H_{out} with ΔH_{out} (s)

3.4.4 Verification results

3.4.4.1 Performance parameters

The results of the verification with regards to flow at H_{bump} (Q_{bump}) and at H_{design} (Q_{design}) are listed in the table.

Based on the results from a test with 1.4l/s@1.00m - 100 % and a corresponding orifice, it can be stated that Mosbaek CEVs are verified to reduce the flow by a factor of 4.45 at Q_{design}.

CEV model	Q_{bump}		Q_{design}	
	Mean⁺ and range (l/s)	Deviation from model charac-teristics (%)	Mean and range (l/s)	Deviation from model character-istics (%)
CEV 1.4l/s @ 1.00m – 100%	1.34 (1.22* – 1.45)	-4.3 (-13* – 3.6)	1.43 (1.42 – 1.45)	2.1 (1.4 – 3.6)
CEV 4.9l/s @ 1.50 m – 100%	4.74 (4.50 – 5.04)	-3.3 (-8.2 – 2.9)	4.78 (4.76 – 4.80)	-2.4 (-2.9 – (-2.0))
CEV 10.5l/s @ 2.00m – 78%	8.17 (7.57 – 8.74)	-0.2 (-7.6 – 6.7)	10.11 (10.09 – 10.12)#	-3.7 (-3.9 – (-3.6))
CEV 10.5l/s @ 2.00m – 100%	10.18 (9.75 – 10.67)	-3.0 (-7.1 – 1.6)	10.56 (10.55 – 10.56)	0.6 (0.5 – 0.6)
Orifice	N/A	N/A	6.36	N/A

⁺) Be aware that the results of Q_{bump} are uniquely influenced by Q_{inflow}

*) For this flow the water level rise was only 0.19 mm/s, while the operational requirement was >0.5 mm/s, this is an explanation for the deviation from the expected.

#) Based on two tests only.

3.4.4.2 Operational parameters

No additional operational parameters than the performance parameters were measured.

This subchapter will therefore not be included in the Statement of Verification.

3.4.4.3 Environmental parameters

No additional environmental parameters than the performance parameters were measured.

This subchapter will therefore not be included in the Statement of Verification.

3.4.4.4 Additional parameters

The user manual and other descriptions were described as complete.

Application of the CEV does not give rise to any special risk or contact to hazardous substances. Though installation in the well is subject to safety risk as all operations in wells, and standard safety precautions therefore have to be taken accordingly.

The CEVs are produced of stainless steel. Today 80 % of the stainless steel on the marked is re-cycled. It is imported from Europe and certain places in Asia. The tested CEVs contain from 6-25 kg stainless steel, and 4.1kWh/kg steel is used in the production. The CEVs are reusable or 100 % recyclable. They have a lifetime of 50 years. The above information is obtained from Mosbaek A/S.

3.4.5 Additional information

The CEV is designed to be effective within a flow range until a certain amount of water is stored in the connected well or basin. This means that if a storm water event exceeds the design criteria, the well or basin where the CEV is located will float over. This situation is not included in the verification.

The CEV is designed with the largest possible opening at the given hydraulic situation. The CEV is most often installed as detachable and if required, obstacles can be removed in this way. At locations with many obstacles in the water, the CEV can be equipped with a grid. All tests are carried out with water without obstacles.

Industrial wastewater and backwater (backwards flow through the CEV) are not included, nor are rapid changes in head and flow. Such changes may occur in special situations (e.g. if pumps are started or stopped).

Characteristics obtained from the experiments are only 100 % valid for applications which have full geometric similarity with the set up defined in Figure 3-2a. For applications with geometries which differ from this figure, the actual characteristic can deviate from the characteristic found from the verification experiment.

3.4.6 Quality assurance and deviations

Prior to testing was performed leakage test and review of calibration certificates for pressure transducers and flowmeters. In addition, calibration tests of pressure transducers were performed on both inlet and outlet side. During testing, internal and external test system audits were performed by DHI and ETA Danmark.

4 Quality assurance

The personnel and experts responsible for quality assurance as well as the different quality assurance tasks can be seen in Table 4-1. All relevant reviews are prepared using the DANETV review report template [5]. Audit during testing has been performed.

Table 4-1 QA plan for the verification

	Internal expert	Verification body		Proposer	External experts
Initials	MJK	MTA	PF	Mosbaek	TL/IW
Tasks					
Specific verification protocol	Review			Review and approve	Review
Test plan		Review	Approve	Review and approve	
Test system at test site			Audit		
Test report		Review		Review	
Verification report	Review			Review	Review
Statement of Verification				Acceptance	Review

Internal review was conducted by Morten Just Kjølby (MJK) and a test system audit was conducted following general audit procedures by certified auditor Peter Fritzel (PF).

Only the verification protocol and verification report require external review according to EU ETV pilot programme GVP [1]. For the verification protocol, external review was performed by Torben Larsen (TL), while the verification report and Statement of Verification have been reviewed by Ian Walker (IW).

The verification body has reviewed and approved the test plan and reviewed the test report. The reviews were performed by Mette Tjener Andersson (MTA), while the approval was given by Peter Fritzel (PF).

5 References

1. EU Environmental Technology Verification pilot programme. General Verification Protocol. Version 1.1 – July 7th, 2014.
2. ETA Danmark. ETV – Verifikation. I30.11, Environmental Technology Verification. 20-11-2013.
3. Gavaskar, A. and Cumming, L.: Cost Evaluation Strategies for Technologies Tested under the Environmental Technology Verification Program. 2001. Battelle.
4. European Commission: Commission Directive on classification, packaging and labelling of dangerous substances. 2001/59/EC. 2001.
5. DANETV Test Centre Quality Manual, 2013.08.13

APPENDICES

APPENDIX A

Terms and definitions

The terms and definitions used by the verification body are derived from the EU ETV General Verification Protocol, ISO 9001 and ISO 17020.

Term	DANETV	Comments on the DANETV approach
Accreditation	Meaning as assigned to it by Regulation (EC) No 765/2008	EC No 765/2008 is on setting out the requirements for accreditation and market surveillance relating to the marketing of products
Additional parameter	Other effects that will be described but are considered secondary	None
Amendment	Is a change to a specific verification protocol or a test plan done before the verification or test step is performed	None
Application	The use of a product specified with respect to matrix, purpose (target and effect) and limitations	The application must be defined with a precision that allows the user of a product verification to judge whether his needs are comparable to the verification conditions
DANETV	Danish centre for verification of environmental technologies	None
Deviation	Is a change to a specific verification protocol or a test plan done during the verification or test step performance	None
Evaluation	Evaluation of test data for a technology product for performance and data quality	None
Experts	Independent persons qualified on a technology in verification	These experts may be technical experts, QA experts for other ETV systems or regulatory experts
General verification protocol (GVP)	Description of the principles and general procedure to be followed by the EU ETV pilot programme when verifying an individual environmental technology.	None
Matrix	The type of material that the technology is intended for	Matrices could be soil, drinking water, ground water, degreasing bath, exhaust gas condensate etc.
Operational parameter	Measurable parameters that define the application and the verification and test conditions. Operational parameters could be production capacity, concentrations of non-target compounds in matrix etc.	None
(Initial) performance claim	Proposer claimed technical specifications of product. Shall state the conditions of use under which the claim is applicable and mention any relevant assumption made	The proposer claims shall be included in the ETV proposal. The initial claims can be developed as part of the quick scan.

Term	DANETV	Comments on the DANETV approach
Performance parameters (revised performance claims)	A set of quantified technical specifications representative of the technical performance and potential environmental impacts of a technology in a specified application and under specified conditions of testing or use (operational parameters).	The performance parameters must be established considering the application(s) of the product, the requirements of society (legislative regulations), customers (needs) and proposer initial performance claims
Procedure	Detailed description of the use of a standard or a method within one body	The procedure specifies implementing a standard or a method in terms of e.g.: equipment used
Proposer	Any legal entity or natural, which can be the technology manufacturer or an authorised representative of the technology manufacturer. If the technology manufactures concerned agree, the proposer can be another stakeholder undertaking a specific verification programme involving several technologies.	Can be vendor or producer
Purpose	The measurable property that is affected by the product and how it is affected.	The purpose could be reduction of nitrate concentration, separation of volatile organic compounds, reduction of energy use (MW/kg) etc.
(Specific) verification protocol	Protocol describing the specific verification of a technology as developed applying the principles and procedures of the EU GVP and the quality manual of the verification body.	None
Standard	Generic document established by consensus and approved by a recognised standardization body that provides rules, guidelines or characteristics for tests or analysis	None
Test/testing	Determination of the performance of a product for measurement/parameters defined for the application	None
Test performance audit	Quantitative evaluation of a measurement system as used in a specific test.	E.g. evaluation of laboratory control data for relevant period (precision under repeatability conditions, trueness), evaluation of data from laboratory participation in proficiency test and control of calibration of online measurement devises.
Test system audit	Qualitative on-site evaluation of test, sampling and/or measurement systems associated with a specific test.	E.g. evaluation of the testing done against the requirements of the specific verification protocol, the test plan and the quality manual of the test body.
Test system control	Control of the test system as used in a specific test.	E.g. test of stock solutions, evaluation of stability of operational and/or on-line analytical equipment, test of blanks and reference tech-

Term	DANETV	Comments on the DANETV approach
		nology tests.
Verification	Provision of objective evidence that the technical design of a given environmental technology ensures the fulfilment of a given performance claim in a specified application, taking any measurement uncertainty and relevant assumptions into consideration.	None

APPENDIX B

Specific Verification Protocol

APPENDIX C

Test Plan

APPENDIX D

Test Report

APPENDIX E

Audit reports