Execution of camera inspections at vacuum sewerage at 4 project sites

Oceanhamnen - Helsingborg

November 29, 2024

Our reference R002-1288399-002RFL-V01-mdg-NL

Responsibility

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1 Introduction

Vacuum toilet systems are a promising solution to reduce drinking water use on the one hand and collect concentrated blackwater from which valuable resources can be recovered on the other hand. Practical experience in the Waterschoon project in Sneek has shown that after 12 years in operation without preventative maintenance, a thick layer of deposits forms in the vacuum pipes. These deposits, or scaling, resulted in blockages of the vacuum pipes, leading to failure of the vacuum system.

A literature review has already been conducted, from which it could be concluded that very little is reported about both the formation, prevention and removal of deposits in vacuum pipes. Given the fact that since Waterschoon multiple projects with vacuum toilets have been realized in the Netherlands and abroad, it is very likely that these projects will eventually face the same problems as seen in Sneek. Therefore, it is important to study:

- The mechanisms of deposit formation in the vacuum pipes
- The formation of deposits over time
- Preventive measures
- Corrective measures

Hence, the ultimate aim is to provide a generic guide for projects with vacuum toilet systems on how to prevent deposits formation (think of periodic preventive maintenance of the pipes) and, for situations like in Sneek, how to correctively remove severe deposits once they have already been formed. As part of achieving this goal, camera inspections have been carried out at four project locations where vacuum toilet systems are applied. This will enable us to gain insight into the formation of deposits over time. In addition, comparing the results between the different project sites will allow for defining potential relationships between piping materials, piping diameter, type of housing, amount of houses connected to the system, etc.

This report describes the camera inspections performed at Oceanhamnen, Helsingborg, Sweden. The description of the location is given in chapter 2. Chapter 3 describes the methods. The results are presented in chapter 4 after which the conclusions and recommendations are shown in chapter 5.

2 Description of location

Oceanhamnen is a new city district in Helsingborg, Sweden. Phase 1 of Oceanhamnen consists of several apartment blocks, offices, hotel, etc.. All buildings are connected to the vacuum toilet system and have been in use and/or inhabited since the period from 2020 - 2022 (see figure below).

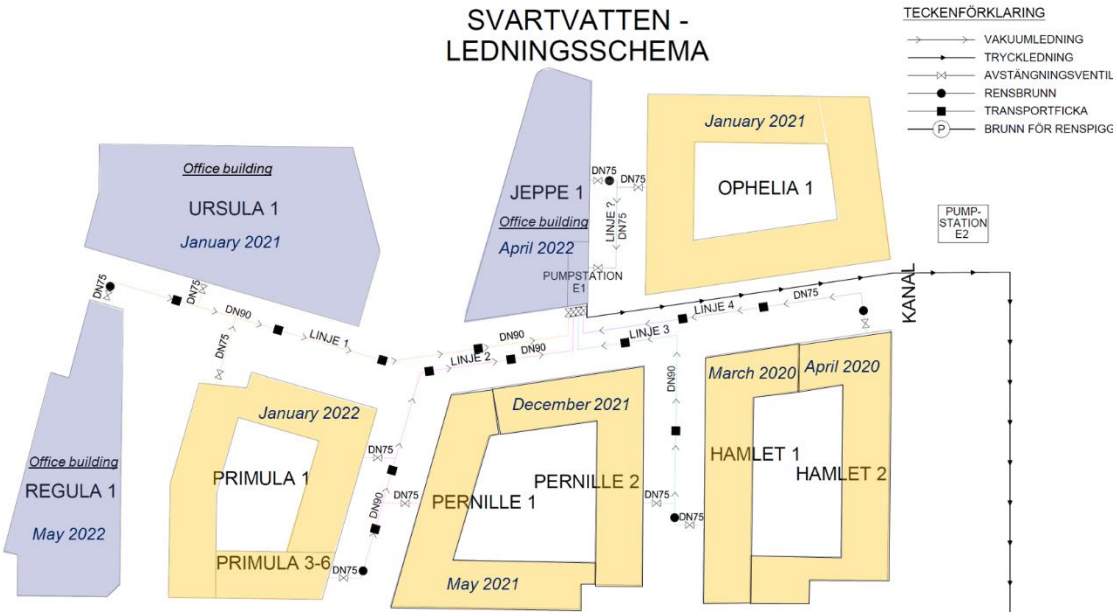

Figure 2.1 Overview of Oceanhamnen phase 1 including the month and year of use. Blue: office and/or hotel, yellow: apartments

The camera inspections were carried out in the indoor vacuum pipes of four buildings:

- Ursula 1 (office building)
- Pernille 1 (apartment block)
- Hamlet 2 (apartment block)
- Ophelia 1 (apartment block)

The following table gives an overview of the characteristics of the inspected buildings. These metadata are relevant for comparing the results between the buildings and with the other project sites.

Table 2.1 Overview metadata of the project location

Characteristic	Specification	
General		
Number of apartments connected to vacuum toilet system	Ursula 1	Not applicable (office)
	Pernille 1	46
	Hamlet 2	46
	Ophelia 1	126 (63 on the inspected line)
In use since	Ursula 1	January 2021
	Pernille 1	May 2021
	Hamlet 2	April 2020
	Ophelia 1	January 2021
Black water and food waste combined?	No, the vacuum toilet system only transports black water. Food waste is collected and treated separately	
Negative pressure vacuum system	-0,42 bar to -0,52 bar	
Vacuum pipes - Indoor		
Material of vacuum pipes	PP (Poloplast)	
Outer diameter of vacuum pipes	Ø 50 – 75 mm	
Cleaning	• 2021-2023: Residents received 0,5L descale gel once a year from NSVA, this also happened in the office building[1] • Automatic descale dosing units have been installed at the horizontal pipes in de basements. Not all of them functioned properly in the first two years, this has improved since Jan 2024 after informing about the issue.[2] The units should dose 10 ml of descale gel every eight hours[3] • Nov-23: High-pressure cleaning + replacement of an indoor pipe in Hamlet 2 due to blockages	
Vacuum pipes - Public area		
Material of vacuum pipes	HDPE (PE 80 SDR17)	
Outer diameter of vacuum pipes	Ø 75 – 90 mm	
Cleaning	All vacuum pipes in the public area have been cleaned using high-pressure flushing (preventative measure), except for line 2 (Primula 1 and 2, these buildings were not inspected). The pipe from Hamlet 2 has been cleaned several times for testing purposes.	

[1] The residents and office buildings received 0.5L descale gel for the toilets once per year between 2021-2023 from NSVA. After that, the properties became responsible to arrange cleaning themselves. It is unknown whether or not the properties dosed and still dose descale gel themselves.
[2] Most descale gel pumps did not function properly in the first two years. In January 2024, NSVA provided information on the issue to the property owners. To our knowledge, the pumps in Hamlet and Ophelia have been checked and ar working. The status of the pumps in Pernille is not known.
[3] It is uncertain whether the units actually dose 10 ml descale gel every 8 hours, because this has not been measured and/or confirmed to our knowledge.

3 Methods

The locations where inspections were performed are shown in the image below. The camera inspections were – in coordination with NSVA - only carried out in the indoor vacuum pipes, not in the public area. The numbers in the dots correspond to the results presented in chapter 4. These locations were selected based on several criteria:

- Presence of accessible inspections points/ openings in the pipes
- Locations far away from and close to the vacuum station
- Horizontal and vertical pipes
- Straight pipes and bends
- Both an apartment block and an office building

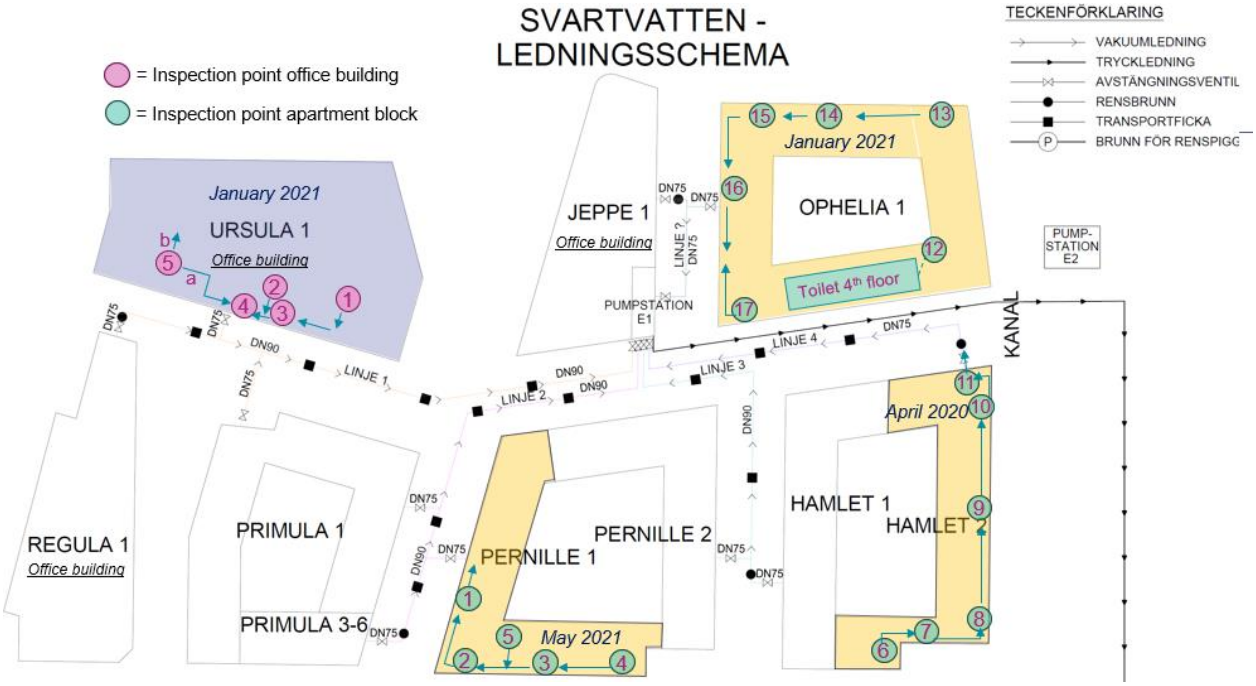

Figure 3.1 Overview of inspection points

The camera inspections were performed with two Ridgid Seesnake cameras, one with a bigger diameter (Compact 2) and one with a smaller diameter (NANOreel). The camera with the widest diameter is self-levelling and was used as standard. In case of smaller pipes, blockages or multiple bends, the smaller camera was used to reach further distances. The smaller camera was not self-levelling. With the camera we could record both video and photos, including the distance in the pipe.

The camera inspections were carried out on June 30 and July 1, 2024.

4 Results

For each building, the results of the camera inspections are described briefly in the following paragraphs. The degree of deposits/ scaling is expressed according to the classification in Table 4.1. For a detailed overview of the images per inspection point made during the camera inspections, we refer to Appendix 1 to Appendix 4.

Table 4.1 Classification of the degree of scaling

Classification	Description
No scaling	No deposits have formed
Minor scaling	Some deposits have formed, the largest part of the pipe is clean
Moderate scaling	Deposits have formed, the largest part of the pipe has scaling
Severe scaling	Deposits have formed, covering the complete pipe
Very severe scaling	A thick layer of deposits have formed, pipe diameter has decreased considerably

4.1 Ursula 1 – Office building

Overall, the camera inspections show that the majority of the inspected horizontal vacuum pipes have moderate to severe scaling. Most pipe segments are completely covered with a thin layer of deposits. The deposits appear to be crystallized and hard.

In most bends, the pipe wall in the outer bend is relatively clean with no to minor scaling. This is probably due to the high rate and abrasive effect of the water in the outer bend. In addition, the pipe walls opposite the connection of another vacuum pipe are clean with no to minor scaling. This can be explained by the abrasive effect of the water from the connected pipe. This effect is only visible for the first approximately 10 - 20 cm after the connecting pipe, after which the pipe is completely covered with deposits again.

In the bend from vertical to horizontal piping after inspection point 4 (via pressure meter), very severe scaling could be observed (Figure 4.1). This was the most severe scaling we observed during the inspections. After the bend, the vacuum pipe leaves the building towards the shut-off valve in the street. Here only minor deposits have formed.

Figure 4.1 Severe deposit formation in the bend right before pipe leaves the building

4.2 Pernille 1 - Apartments

In Pernille, one long horizontal line was filmed up until the point where the pipe exits the building (point 1, 2, 3 and 4). Overall, the results show moderate to severe deposit formation as most pipe segments are completely covered with a layer of deposits. The majority of the deposits appear to be crystallized and hard. There is no clear relationship between the severity of the deposits and the distance from the vacuum station and/or number of toilets connected in Pernille 1.

The pipe segments inspected at point 1, 3 and part of point 4 show quite severe deposits, sometimes narrowing the pipe diameter. The scaling in the pipe segment between points 2 and 1 is slightly less severe and shows a ‘highway pattern’ (deposits all around the pipe, except the bottom, see image below).

Figure 4.2 'Highway pattern' in the pipe segment inspected from point 2 towards point 1

Contrary to the results of Ursula 1, the pipe walls in bends and at connecting pipes are only slightly cleaner than the rest of the pipe. Possibly this is due to a lower blackwater flow through the inspected pipe, resulting in less abrasive effects. Less feces from toilet visits in office buildings (like Ursula 1) than in apartment buildings (like Pernille) could also be an possible explanation, but as we’ve seen similar results to Ursula 1 at Hamlet 2 (apartments), see next paragraph, this is unlikely.

At point 4, the camera was inserted at the automatic descaling gel dosing unit. At this point, descale gel is dosed (supposedly 10 ml/8h). At the start of this pipe, no vacuum toilets are

connected, so no deposits had formed. Only after approximately 1 m, the first vacuum pipe connects to the inspected line. Due to dosing descale gel in the dead end of the pipe, the effect of the descaling gel on the deposits is not visible.

Point 5 is an inspection opening in the ceiling of the garage. Only one or two apartments are connected to this line segment. At the start of the line, no to minor scaling is present. The scaling severity increases with the distance in the pipe. After approximately 3,5 m, the complete pipe is covered with deposits: a thin layer at the top and a thicker layer at the bottom.

4.3 Hamlet 2 - Apartments

In Hamlet 2, one long horizontal line was filmed up until the shut-off valve in the public area (point 6-11). Overall, the results show moderate to severe deposit formation as most pipe segments are completely covered with a layer of deposits. The majority of the deposits appear to be crystallized and hard.

Similar to Ursula 1, the pipe walls in the outer bends are relatively clean with no to minor scaling. Also the pipe walls opposite the connection of another vacuum pipe are clean with no to minor scaling. Further down the pipe, towards the vacuum system, the bends and pipe walls opposite connections are less clean than at the start and middle of the pipe.

From point 8 onwards, the pipe was cleaned using high-pressure flushing in November 2023 (see figure below). Interestingly, no clear effect of this cleaning is visible compared to the images of point 6 and 7. Figure 4.4 shows that the severity of scaling is similar in the vacuum pipes after point 6, 7 and 8.

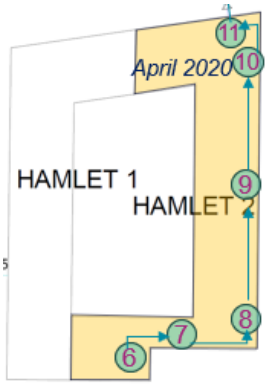

Figure 4.3 Inspection points

Point	Distance in vacuum pipe			
Point 6	0 m	1,61 m	3,63 m	6,32 m
Point 7	0 m	1,38 m	7,72 m	12,57 m
Point 8	0 m	1,99 m	15,86 m	23,33 m

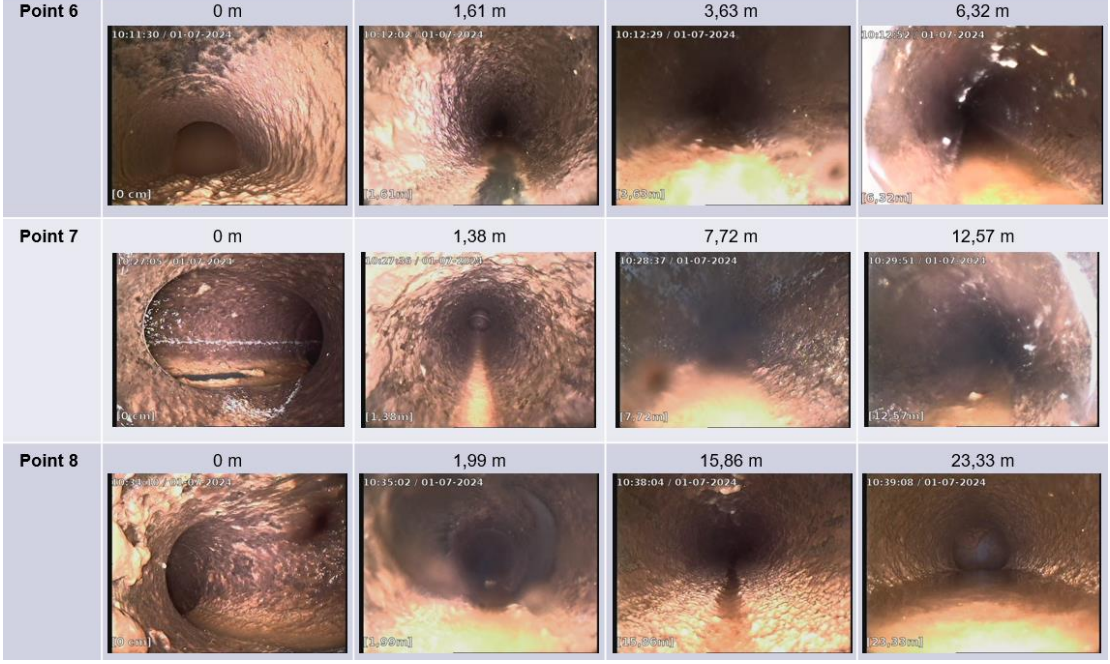

Figure 4.4 Comparison severity of scaling in the vacuum pipe from point 6, 7 and 8

4.4 Ophelia 1 - Apartments

In Ophelia 1, one full horizontal line was filmed up until the shut-off valve in the public area (point 13-16) and one segment of the second horizontal line (point 17). Overall, the results show moderate to severe deposit formation as most pipe segments are completely covered with a layer of deposits. At some locations, a thick layer of deposits is visible, forming very severe deposits narrowing the pipe (see Figure 4.5). The majority of the deposits appear to be crystallized and hard. There is no clear relationship between the severity of the deposits and the distance from the vacuum station and/or number of toilets connected.

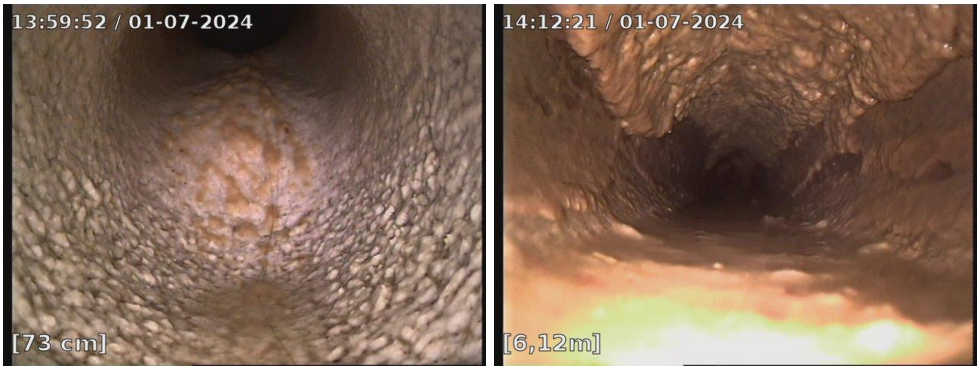

Figure 4.5 Thick layer of deposits at inspection point 14 (left) and 15 (right)

Similar to Pernille 1, the pipe walls in bends and at connecting pipes are only slightly cleaner than the rest of the pipe. Possibly this is due to a lower blackwater flow through the inspected pipe, resulting in less abrasive effects. Further down the pipe, towards the vacuum station, the bends and pipe walls opposite connections have more severe deposits than the bends at the start and middle of the pipe.

At the pipe segment between point 13 and point 14, there is an automatic descale gel dosing unit (10 ml every 8 hours). The descale gel removes/ prevents the formation of scaling at the bottom of the pipe, as can be seen in de images below. The effect is however limited, because the clean bottom is observable only from 10 cm before the dosing point to a maximum of 1,1 m after the dosing point.

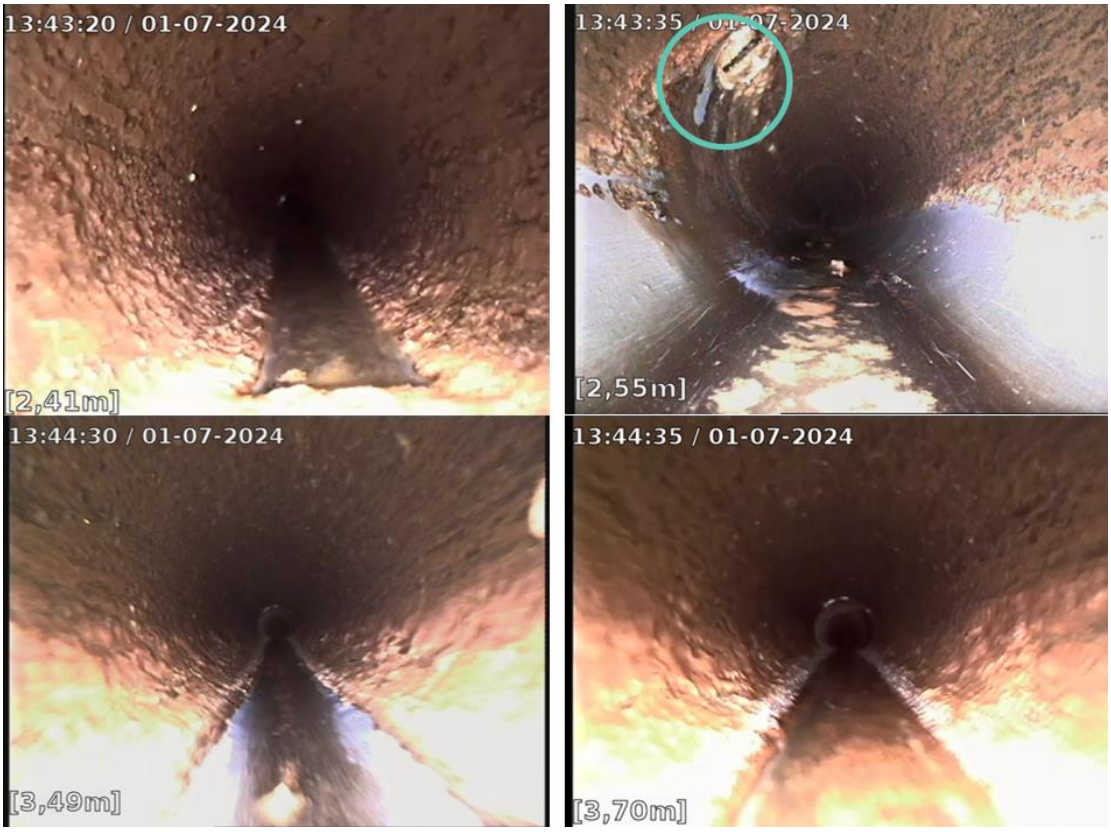

Figure 4.6 Effect of automatic descale dosing. Top left: ca. 0,1m before dosing, top right: circle shows dosing point, bottom left: ca. 0,9 m after dosing, bottom right: ca. 1,1 m after dosing

In addition to the horizontal pipe, a vertical pipe was inspected by passing the camera through the pipe of a dismantled toilet on the 4th floor (point 12). Only minor scaling is present for the first 5 meters down. At 5,7m an extra toilet connects to the pipe. The amount of deposits increases around this connection, both above and below. This is probably due to splashing of blackwater from the horizontal pipe into the vertical pipe. The pipe walls opposite the connections are clean. The severity of scaling appears to increase with the depth of the vertical pipe and the number of

connected toilets. Descaling gel was last dosed into the toilet by the apartment owner in April/March 2024.

4.5 Comparison between buildings

Table 4.2 Comparison of building properties and degree of scaling

Description	Ursula 1	Pernille 1	Hamlet 2	Ophelia 1
Type of use	Office building	Apartments	Apartments	Apartments
In use since	January 2021	May 2021	April 2020	January 2021
Time in operation	3 years & 5 months	3 years & 1 month	4 years & 2 months	3 years & 5 months
Number of connected apartments	Not applicable	46	46	126 (63 on inspected line)
Degree of scaling in horizontal pipes	Moderate to severe	Moderate to severe	Moderate to severe	Moderate to severe

Table 4.2 gives a summary of the buildings properties and the observed degree of scaling. There are no significant differences in the degree of scaling in the horizontal pipes between the buildings. This means that there appears to be no clear relationship between the degree of scaling and the type of use of the building (office or apartments) or number of connected apartments. In addition, Hamlet 2 is the oldest building inspected and the vacuum toilet system has been in operation for approximately 1 year longer than in the other buildings. When comparing the results of Hamlet 2 to the results of the other buildings, there appears to be no relationship between this additional year of usage and the severity of scaling.

In all buildings we saw that most outer bends and pipe walls opposite connections are cleaner than the rest of the pipe (see Figure 4.7). This pattern was especially visible in Ursula 1 and Hamlet 2, whereas in Pernille 1 and Ophelia 1 the bends and connections were only slightly cleaner. In Hamlet 2 and Ophelia 1, the abrasive effect in bends and at connections appeared to become less further down the pipe, towards the vacuum station. Overall, there was no clear relationship between the distance in the pipe and the severity of the deposits.

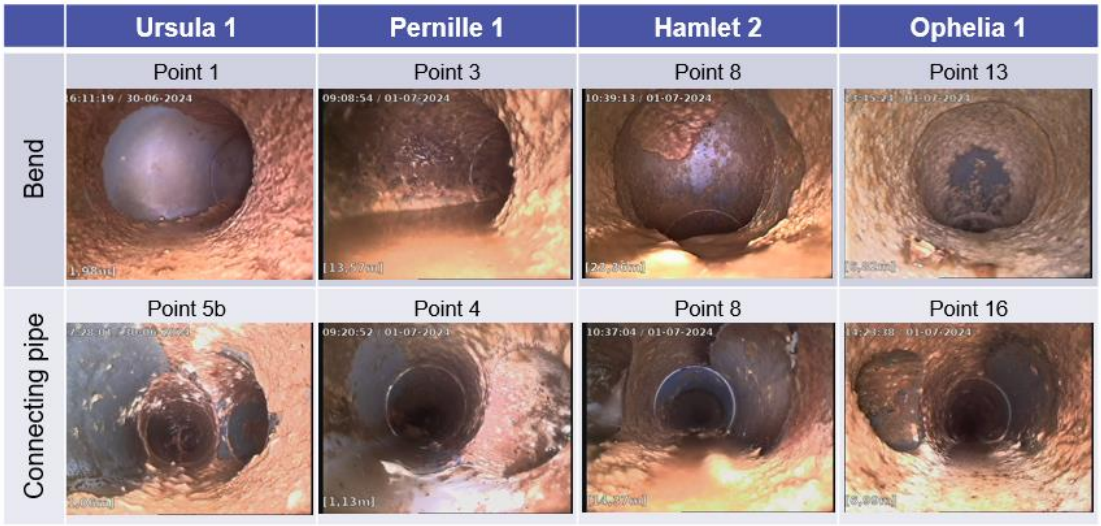

Figure 4.7 Examples of the abrasive effect of black water in bends and at pipe walls opposite connecting pipes

5 Conclusions and recommendations

5.1 Conclusions

Based on the camera inspection, the following conclusions can be drawn:

- All buildings have moderate to severe scaling in the horizontal vacuum pipe, consisting of hard crystallized deposits.
- A few locations have thick deposits narrowing the diameter of the horizontal pipe, posing a risk of blockages
- In most bends, the pipe walls of the outer bend are relatively clean due to the abrasive effect of the blackwater
- The pipe walls opposite connections of vacuum pipes are relatively clean due to the abrasive effect of the blackwater
- In the horizontal pipes, no relationship could be observed between the degree of scaling and the distance in the pipe/ number of toilets connected
- In the vertical vacuum pipe, the degree of scaling increases from minor scaling to moderate/severe scaling with the depth of the vertical pipe and the number of connected toilets
- Since most pipe walls were covered with deposits, it can be concluded that manual and automatic descale dosing which is currently applied does not prevent scale formation at the used dosage
- When comparing the different buildings, we found no relationship between the degree of scaling in the horizontal pipes and the number of apartments connected, the operation time of the vacuum system and type of use of the building

5.2 Recommendations

Based on the findings, it is recommended to clean the indoor pipes to prevent further scaling formation and reduce the risk of blockages. It is important to take into account the type of scaling: soft viscous deposits or hard crystalized deposits. The camera inspections together with some pipe sections that were dismantled have shown that the majority of the deposits are hard and crystalized, for which physical or chemical cleaning methods such as high-pressure flushing or strong acid recirculation are likely most effective. Because the scaling seems to be hard and crystallized, it is expected that flushing the pipes with foam balls, as is applied in Hamburg as preventive measure, will not be effective. This also accounts for flushing with crushed ice, little to no effect is expected because of the hard scaling present. In addition, it is recommended to monitor the current descale dosing to quantify the actual dose and frequency.

After cleaning the pipes, it is recommended to periodically clean the pipes as a preventive measure. Possible preventive measures foreseen are: 1) high-pressure flushing, 2) flushing with foam balls, and 3) dosing acid with a higher dosage than currently applied. With these preventive measures, the formation of hard crystalized deposits is prevented or impaired.
At this moment it is not known which preventive measures are most effective and what the frequency or dosage amount should be. In the near future, further research and gaining new

knowledge is expected which ultimately should provide a generic guide on how to best prevent deposits at vacuum toilet systems.

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Appendix 1 Camera images Ursula 1

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Appendix 1a Point 1

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Relatively clean bend at the end

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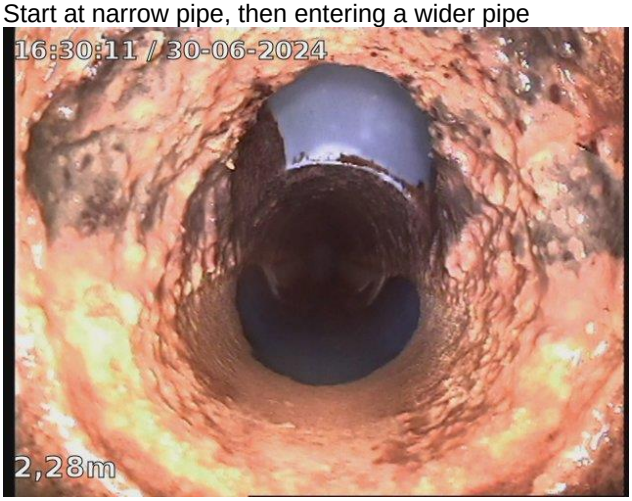
Appendix 1b Point 2

In the recording at inspection point 2, the distance measurement was incorrect due to unknown reasons. The camera was inserted into the pipe for approximately 2,2 meters until we reached the shut-off valve.

Start at narrow pipe, then entering a wider pipe



At the top the connection of another vacuum pipe is visible. Immediately after the connection, the pipe wall opposite the connection is clean

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Relatively clean bend at the end

Our reference R002-1288399-002RFL-V01-mdg-NL

Wider pipe, shut-off valve is visible at the end of the pipe

Our reference R002-1288399-002RFL-V01-mdg-NL

Wider pipe, shut-off valve is visible at the end of the pipe

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Appendix 1c Point 3

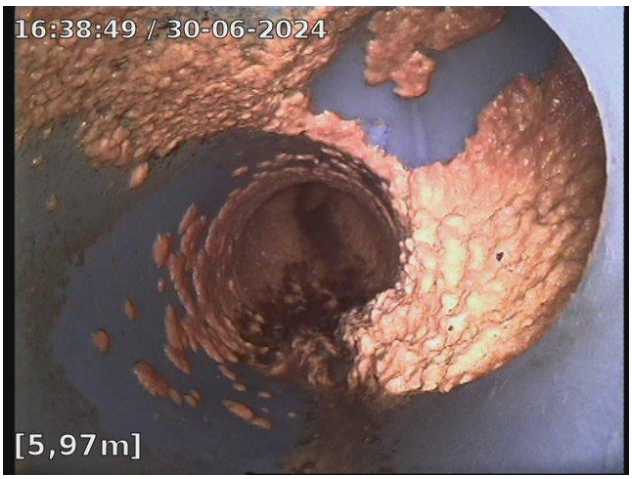
At the top the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

Relatively clean bend at the end

Our reference R002-1288399-002RFL-V01-mdg-NL

Our reference R002-1288399-002RFL-V01-mdg-NL

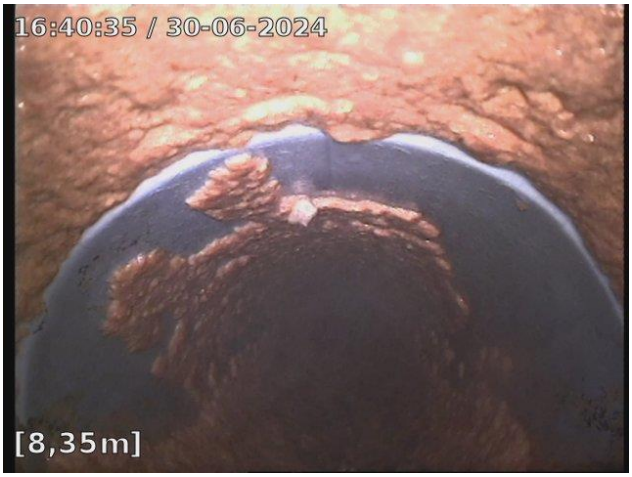
Relatively clean bend at the end



On the right the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

Our reference R002-1288399-002RFL-V01-mdg-NL

Relatively clean bend at the end



Just before the pipe goes outside / leaves the building

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The smaller camera was used to reach deeper into the pipes, this camera is not self-levelling. The results are shown below.

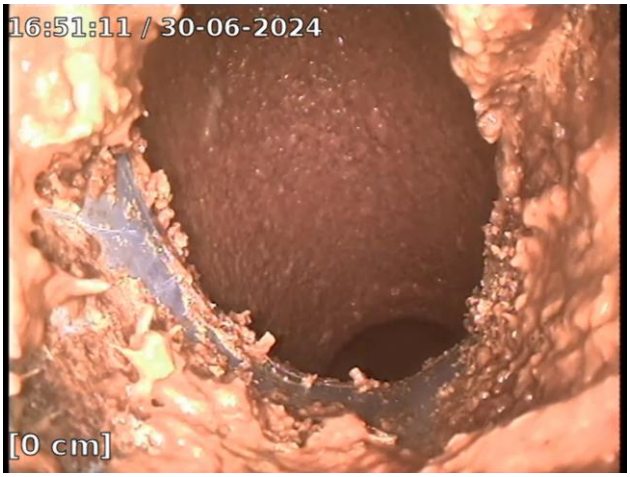
Smaller camera, right side is the bottom of the pipe

Smaller camera, right side is the bottom of the pipe

Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 1d Point 4

Camera entered the pipe at the opening of the pressure meter, inspection towards the public area.



Entering through the opening of the pressure meter, vertical pipe

Bend from vertical to horizontal pipe: a lot of scaling present in the bend

The bend was disconnected piece by piece, the bend had very severe scaling, right after the bend, the scaling decreased rapidly.

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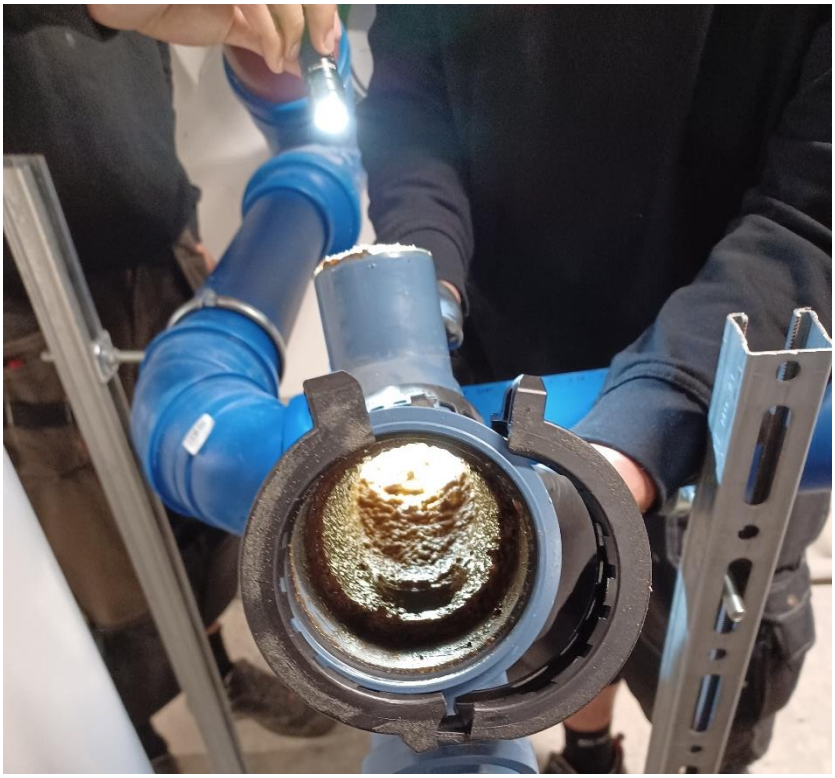

Vertical pipe towards the bend

Start of the bend

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Bend

Right after the bend

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Some pieces of scaling removed from the band

After the bend

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Shut-off valve in the street

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Appendix 1e Point 5a

Camera inspections towards public area/ towards vacuum station

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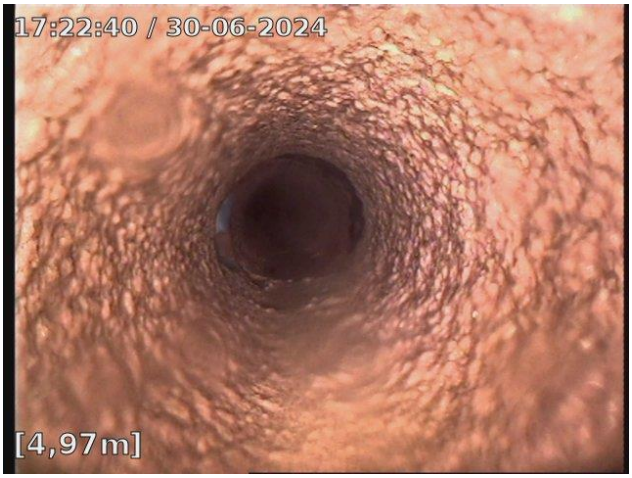
Entering a transport pocket

Our reference R002-1288399-002RFL-V01-mdg-NL

Leaving a transport pocket



On the left the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

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Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 1f Point 5b

Camera inspections away from vacuum station / opposite direction of vacuum station / point 5a

Our reference R002-1288399-002RFL-V01-mdg-NL

On the right the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

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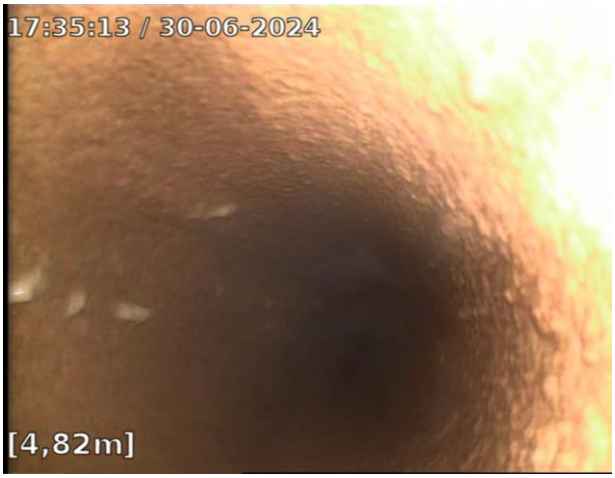
The smaller camera was used to reach deeper into the vacuum pipe. This camera is not self-levelling. The results with the smaller camera are shown below.

Smaller camera, the bottom of the image is the bottom of the pipe



Smaller camera. Vertical pipe, moving upwards

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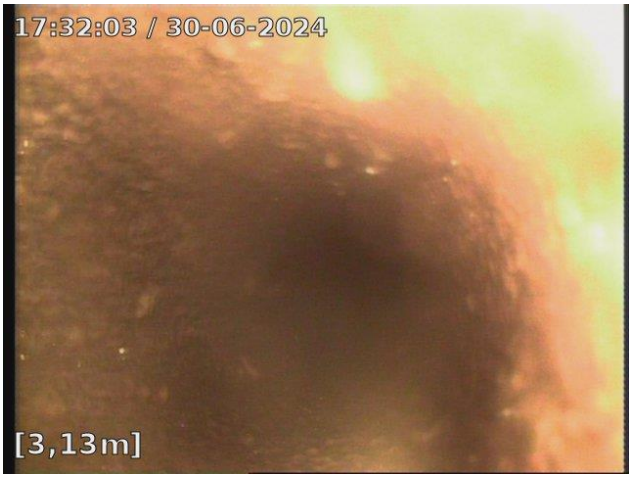
Smaller camera, into the connecting pipe which is visible in the images with the larger camera at 1,06 m (see images above).



Smaller camera, top right is the bottom of the pipe

Smaller camera, bend

Our reference R002-1288399-002RFL-V01-mdg-NL

Smaller camera, top right is the bottom of the pipe

Appendix 2 Camera images Pernille 1

Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 2a Point 1

Our reference R002-1288399-002RFL-V01-mdg-NL

Our reference R002-1288399-002RFL-V01-mdg-NL

Our reference R002-1288399-002RFL-V01-mdg-NL

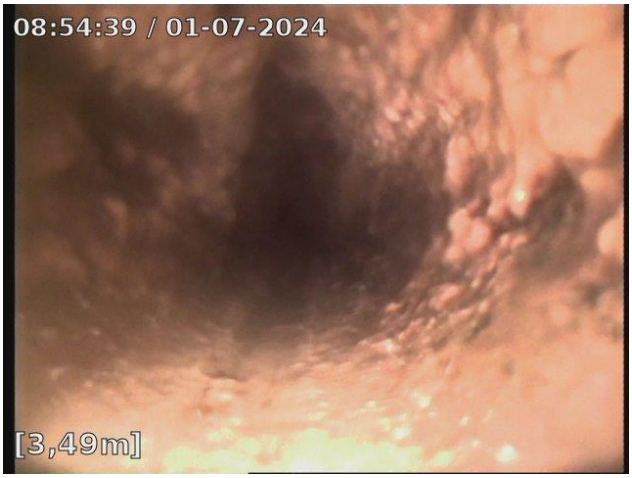
Appendix 2b Point 2

Bend

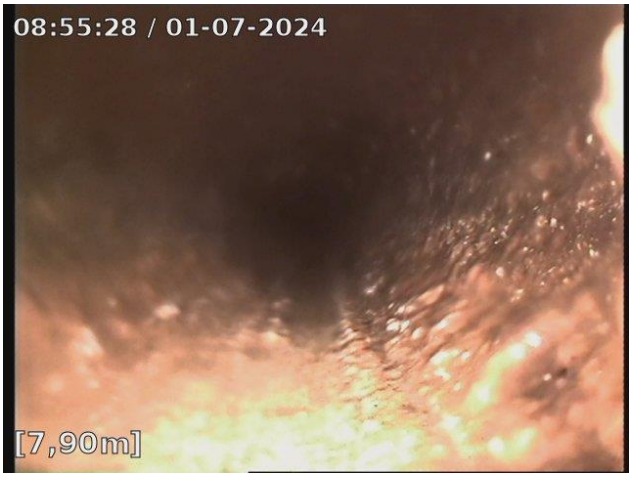
Bend

Our reference R002-1288399-002RFL-V01-mdg-NL

Bend



Our reference R002-1288399-002RFL-V01-mdg-NL



Our reference R002-1288399-002RFL-V01-mdg-NL

On the right, another vacuum pipe is connected

Thick layer on the ceiling, bottom is clean

Our reference R002-1288399-002RFL-V01-mdg-NL

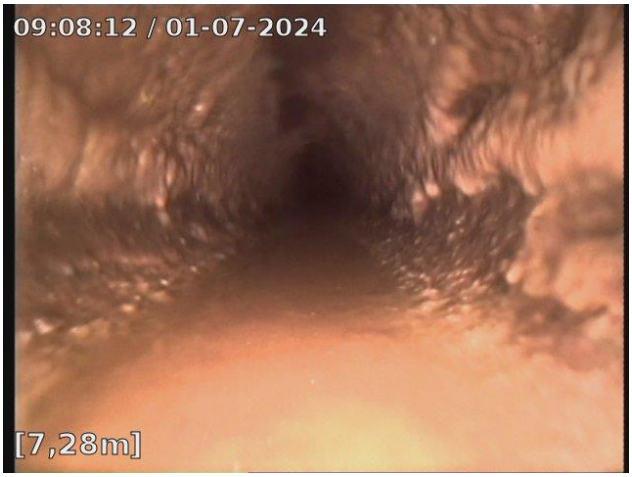
Start of transport pocket at inspection point 1

Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 2c Point 3

Bend

Our reference R002-1288399-002RFL-V01-mdg-NL



Our reference R002-1288399-002RFL-V01-mdg-NL

Bend

Immediately after the bend

Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 2d Point 4

Camera inserted at the descaling gel dosing point. No vacuum sewer was connected to this point (which is why the piping is clean at the start)

Our reference R002-1288399-002RFL-V01-mdg-NL

On the right the connection of the first vacuum pipe is visible you see the first vacuum pipe connected to the line. The pipe wall opposite the connection is relatively clean The deposits in the front are probably due to splashing of the black water into the main pipe.

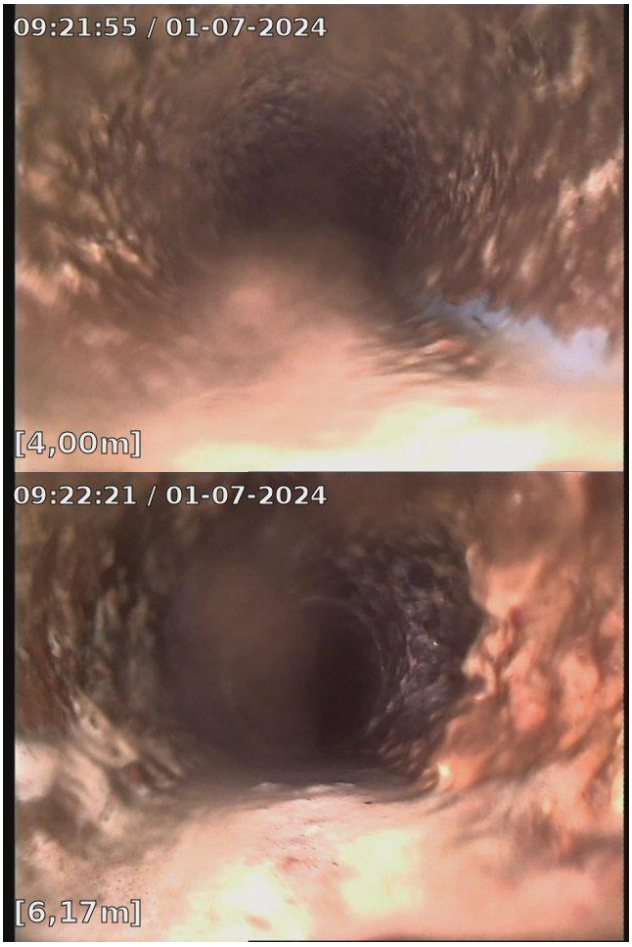
Our reference R002-1288399-002RFL-V01-mdg-NL

On the right the connection of another vacuum pipe is visible. The pipe wall opposite the connection is cleaner

Bend start of transport pocket

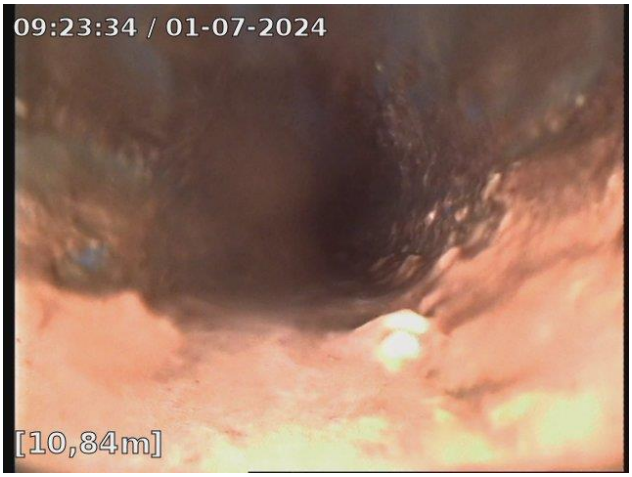
Bend end of transport pocket

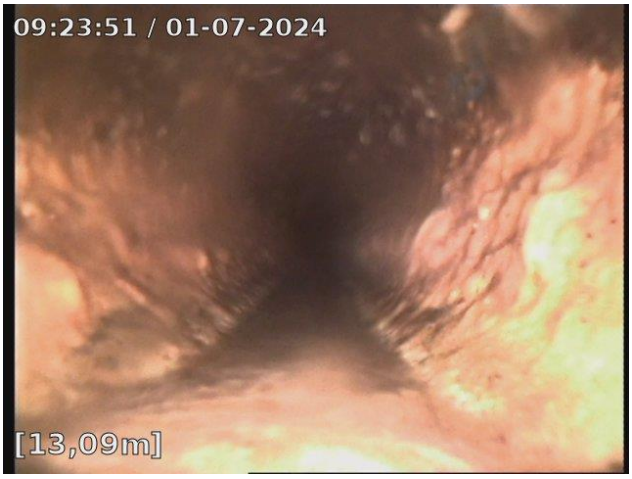
Our reference R002-1288399-002RFL-V01-mdg-NL



On the right the connection of another vacuum pipe is visible. The pipe wall opposite the connection is nót cleaner

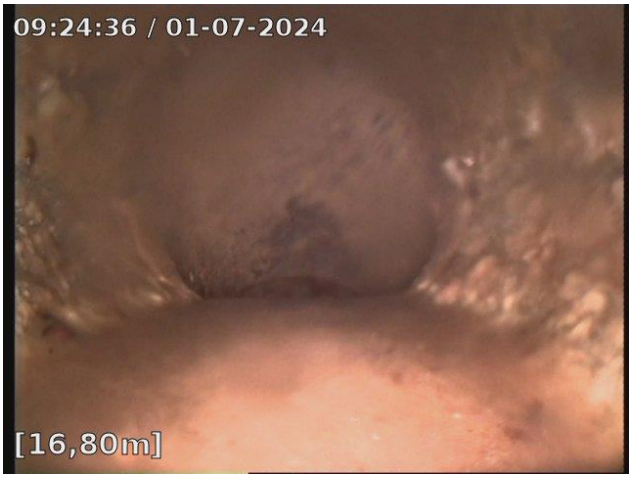
Our reference R002-1288399-002RFL-V01-mdg-NL



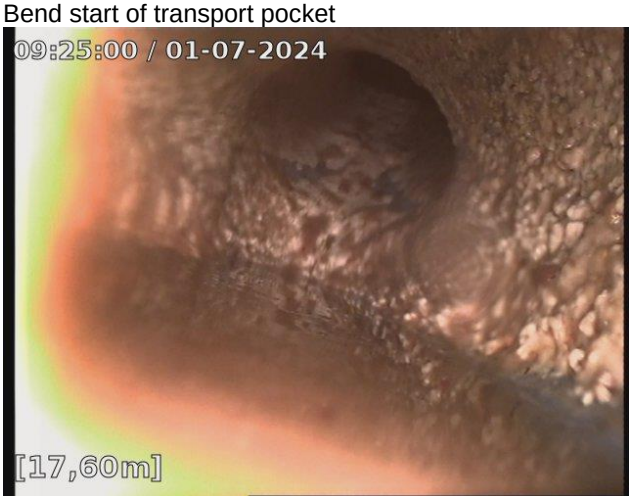


On the right the connection of another vacuum pipe is visible. The pipe wall opposite the connection is a bit cleaner

Our reference R002-1288399-002RFL-V01-mdg-NL



Bend start of transport pocket



Bend end of transport pocket

Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 2e Point 5

Location 5a is the inspection opening in de insulation material of the ceiling of the garage. The small camera was used. This camera does not have a self-levelling camera head to keep the image upright. In case the image is tilted, it is indicated which side is the bottom of the pipe.

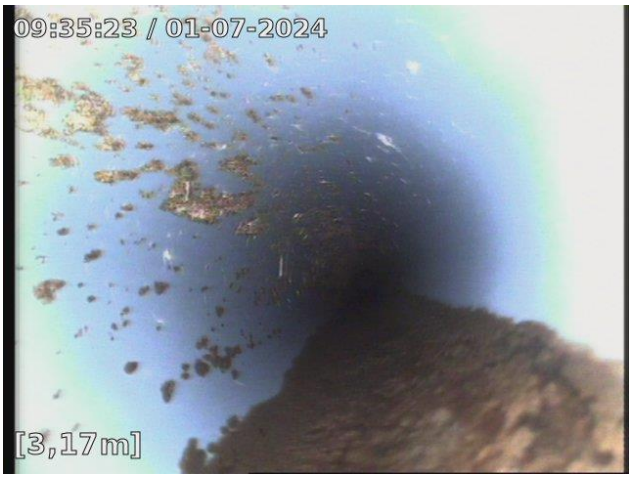
The right side of the image is the bottom. The connection of the first vertical vacuum pipe on this line is visible on the left side of the image. The pipe wall opposite the connection cleaner

The deposits have formed at the bottom of the pipe

Our reference R002-1288399-002RFL-V01-mdg-NL

The deposits have formed at the bottom of the pipe

The deposits have formed at the bottom of the pipe



The deposits have formed at the bottom of the pipe

Our reference R002-1288399-002RFL-V01-mdg-NL

The left side of the image shows the bottom of the pipe

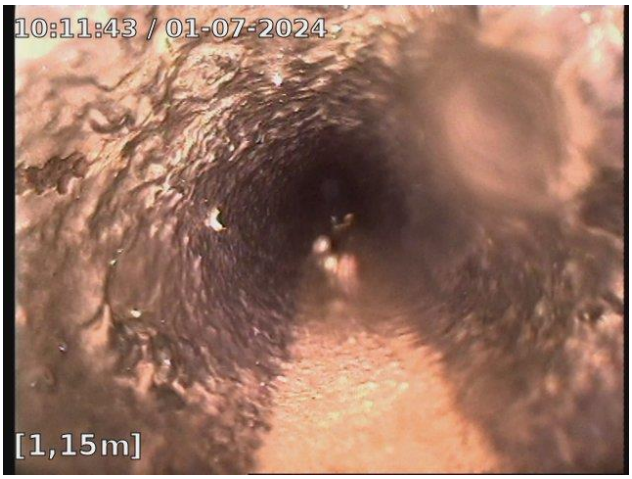
The right side of the image shows the bottom of the pipe

Appendix 3 Camera images Hamlet 2

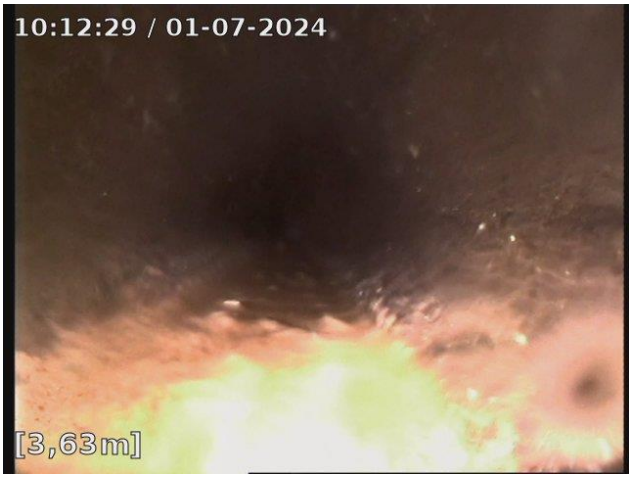
Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 3a Point 6

Bend into the transport pocket



Our reference R002-1288399-002RFL-V01-mdg-NL



Bend

Our reference R002-1288399-002RFL-V01-mdg-NL

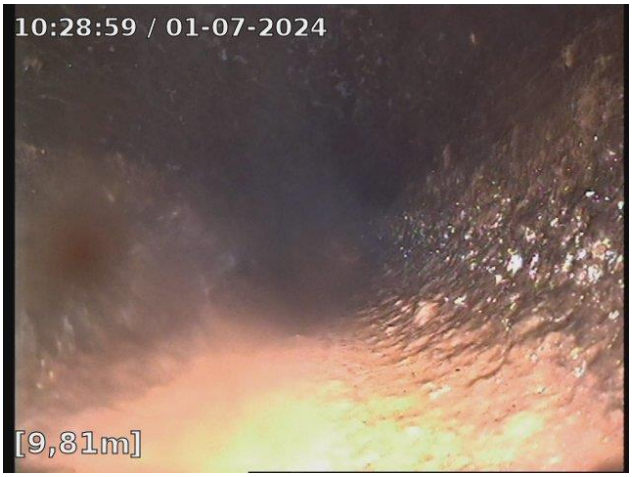
Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 3b Point 7

Bend

Our reference R002-1288399-002RFL-V01-mdg-NL

Our reference R002-1288399-002RFL-V01-mdg-NL



Bend towards the left

Immediately after the bend

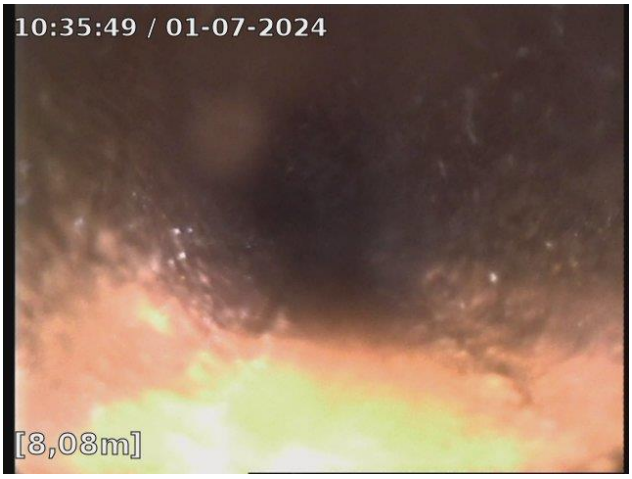
Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 3c Point 8

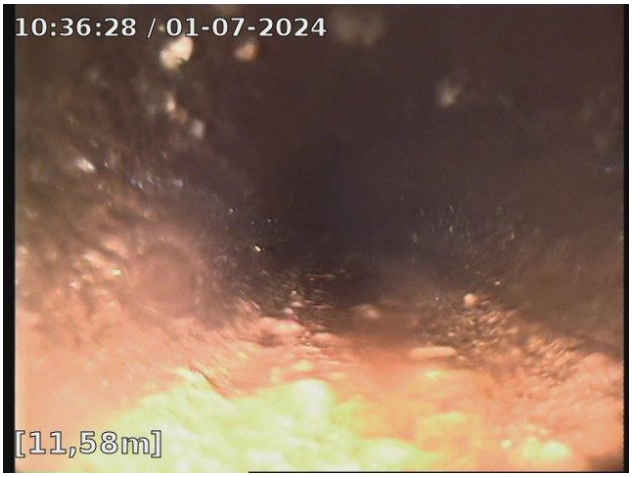
In November 2023, this pipe segment was cleaned using high-pressure flushing.

On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

Our reference R002-1288399-002RFL-V01-mdg-NL



Our reference R002-1288399-002RFL-V01-mdg-NL



On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is cleaner.

Our reference R002-1288399-002RFL-V01-mdg-NL

Here, the transition to a short pipe segment of another type of material is visible. Unknown why this segment is of another material type. Deposits seem to attach less well to this material, since the piping is very clean compared to the segments before and after.

Our reference R002-1288399-002RFL-V01-mdg-NL

Bend into transport pocket

Bend out of transport pocket

Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 3d Point 9

In this piping segment, the transport pocket has been replaced due to blockages.

Our reference R002-1288399-002RFL-V01-mdg-NL

On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is cleaner

Our reference R002-1288399-002RFL-V01-mdg-NL

On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

Our reference R002-1288399-002RFL-V01-mdg-NL

Our reference R002-1288399-002RFL-V01-mdg-NL

Bend

Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 3e Point 10

Inspection point in the technical room

Our reference R002-1288399-002RFL-V01-mdg-NL

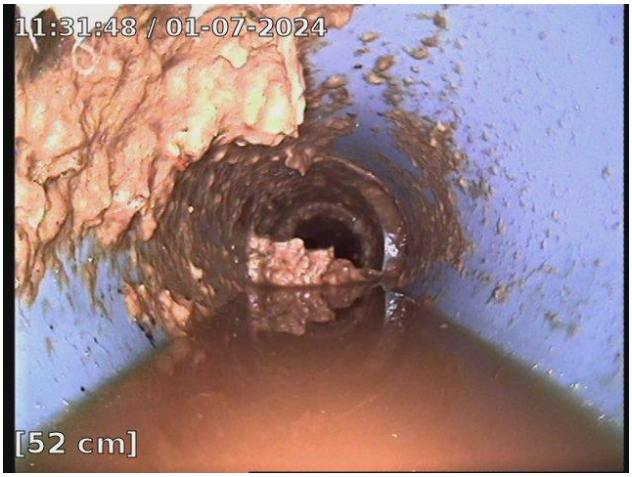
Downwards bend

Our reference R002-1288399-002RFL-V01-mdg-NL

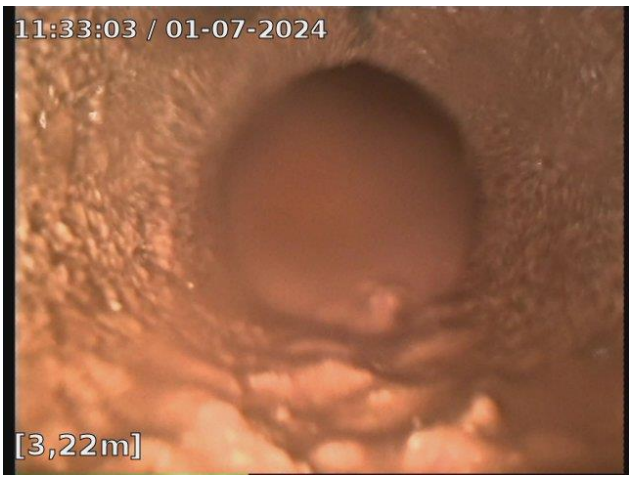
Appendix 3f Point 11

The camera was inserted through the Perrot coupling, as shown in the following image.

Our reference R002-1288399-002RFL-V01-mdg-NL



Toilet paper is visible



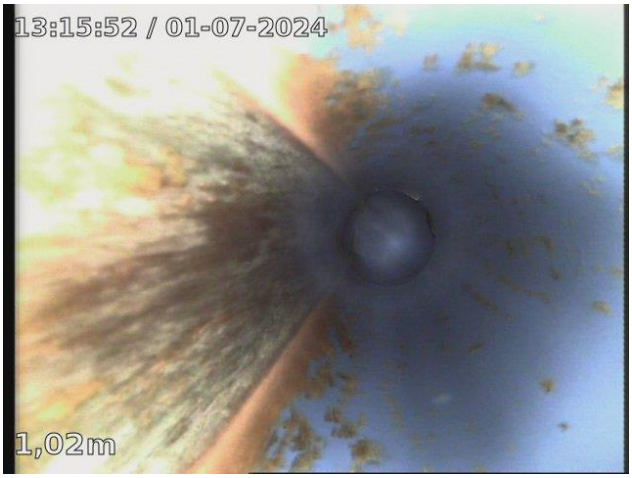
Shut-off valve in the public area

Appendix 4 Camera images Ophelia 1

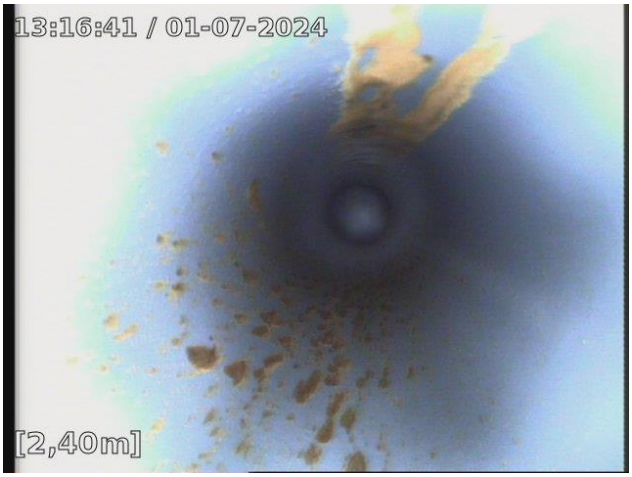
Our reference R002-1288399-002RFL-V01-mdg-NL

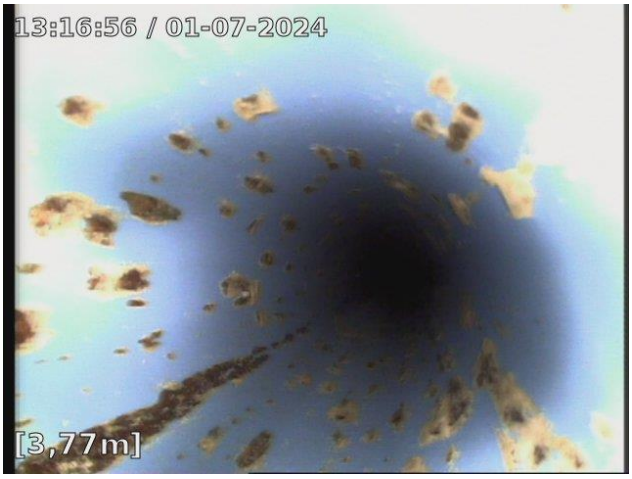
Appendix 4a Point 12

The small camera was inserted at a toilet on the 4th floor into the vertical pipe.



Our reference R002-1288399-002RFL-V01-mdg-NL





Our reference R002-1288399-002RFL-V01-mdg-NL

Connection of another vacuum pipe. The pipe wall opposite the connection is clean

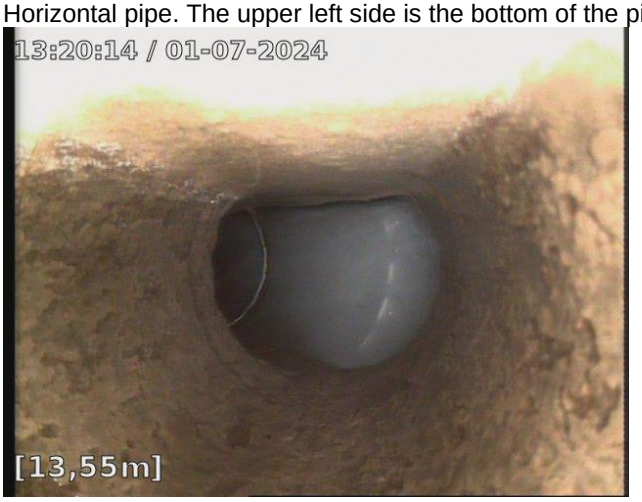
Our reference R002-1288399-002RFL-V01-mdg-NL

On the right, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

Our reference R002-1288399-002RFL-V01-mdg-NL

Horizontal pipe. The upper left side is the bottom of the pipe.

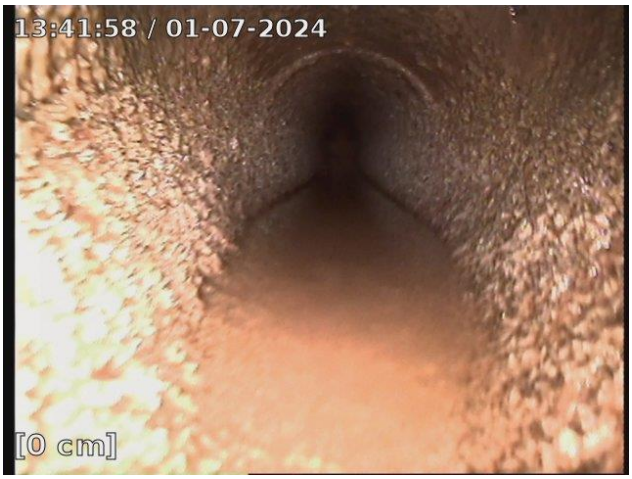


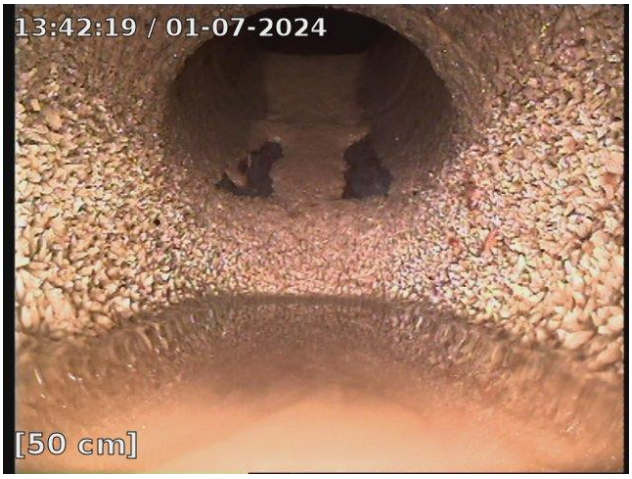
Horizontal pipe, bend. The top of the image is the bottom of the pipe.

Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 4b Point 13

Crystals are clearly visible.





Our reference R002-1288399-002RFL-V01-mdg-NL

Upward bend out of transport pocket.

This image is taken just before the dosing point of the descaling gel. The suddenly clean bottom of the pipe is probably caused by the descaling gel.

Our reference R002-1288399-002RFL-V01-mdg-NL

The dosing point of the descaling gel is indicated with the blue circle (10 ml every 8 hours). The effect can be seen at the bottom of the pipe

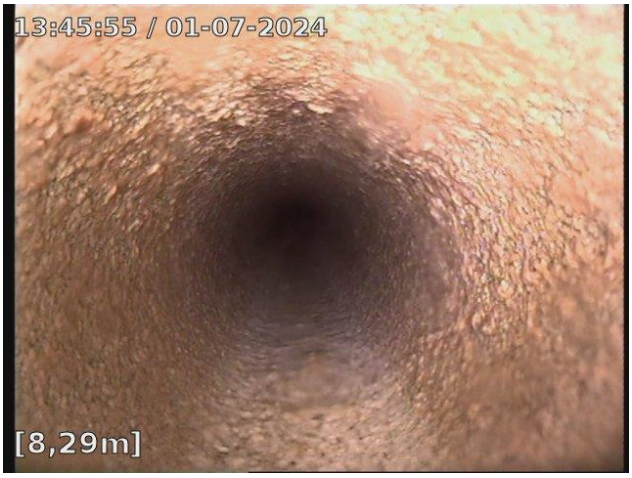
On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

Our reference R002-1288399-002RFL-V01-mdg-NL

Bend into transport pocket

Bend out of transport pocket



Our reference R002-1288399-002RFL-V01-mdg-NL

Our reference R002-1288399-002RFL-V01-mdg-NL

Shut-off valve

Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 4c Point 14

This shows a bump of deposits in the pipe in a bend, significantly narrowing the pipe diameter

Our reference R002-1288399-002RFL-V01-mdg-NL

Our reference R002-1288399-002RFL-V01-mdg-NL

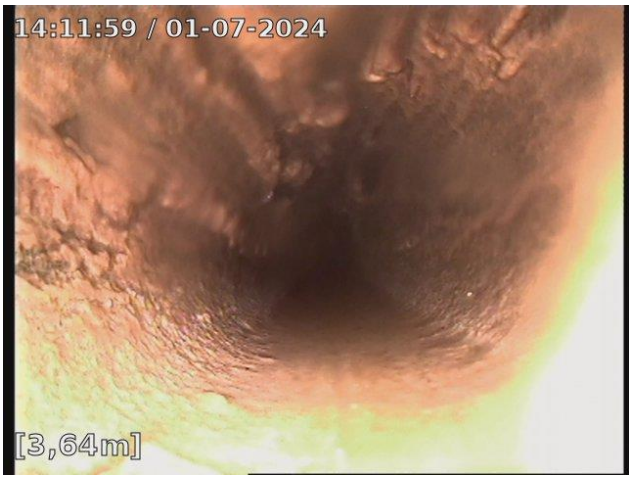
On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 4d Point 15

Thick layer of deposits



Our reference R002-1288399-002RFL-V01-mdg-NL

Thick layer of scaling on the top of the pipe

Bend

Our reference R002-1288399-002RFL-V01-mdg-NL

‘highway effect’

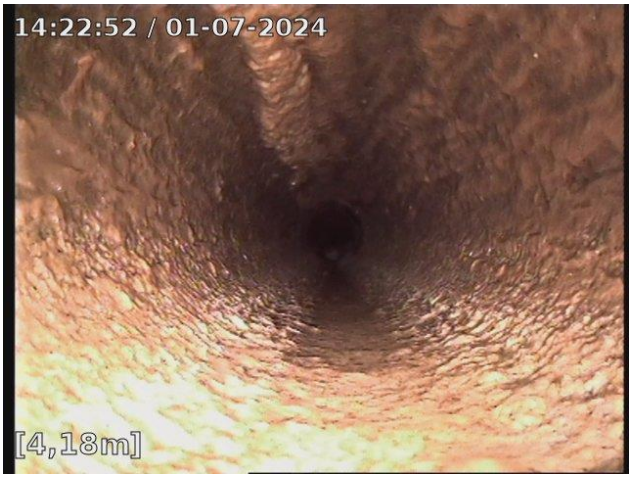
Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 4e Point 16

Bend out of transport pocket

Our reference R002-1288399-002RFL-V01-mdg-NL

On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is a bit cleaner



On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is clean

Our reference R002-1288399-002RFL-V01-mdg-NL

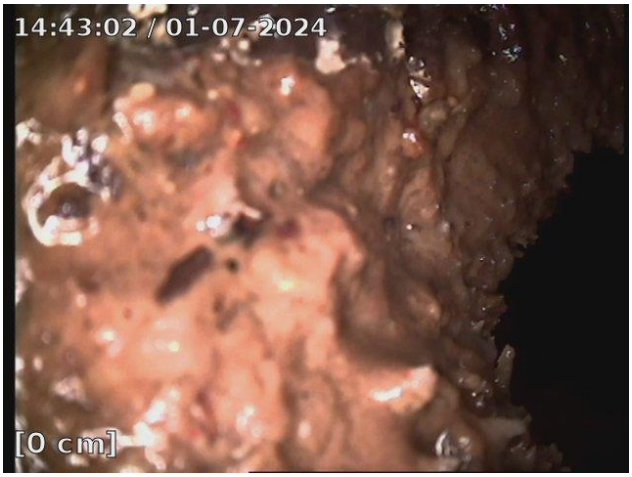
On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is a bit cleaner.

Our reference R002-1288399-002RFL-V01-mdg-NL

On the left, the connection of another vacuum pipe is visible. The pipe wall opposite the connection is a bit cleaner.

Our reference R002-1288399-002RFL-V01-mdg-NL

Appendix 4f Point 17



Downward bend

Our reference R002-1288399-002RFL-V01-mdg-NL

Bend to the right

Our reference R002-1288399-002RFL-V01-mdg-NL

Bend to the right