

SCHLUFF VACUUM SEWERAGE SYSTEM

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Literature and lectures

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Vacuum Sewerage System

New knowledge leads to a reliable transport system

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The following article shows a new development that gains a basic significance in technical as well as in economic matters.

Editor

1.0 General

The sewage disposal has mostly been completed in our country, the cities and larger communities. Increased environmental awareness, especially the obligation of the communities to deposit liquid waste according to law urgently call for the extension of sewage systems in the rural areas. With low population density, insufficient downgrade, high ground water level or unfavourable below ground conditions in an usual gradient system the slop disposal can only be executed with extremely high costs. The pressurized sewerage, also called vacuum sewerage system, is an economical alternative towards the collection of municipal and industrial liquid waste. It was invented by the Swedish Joel Liljendahl and for the first time used for sewerage of an area located in the north of Stockholm. The vacuum sewerage system is used in Germany in several villages.

2.0 Components of the vacuum sewerage

The system mainly consists of the following parts:

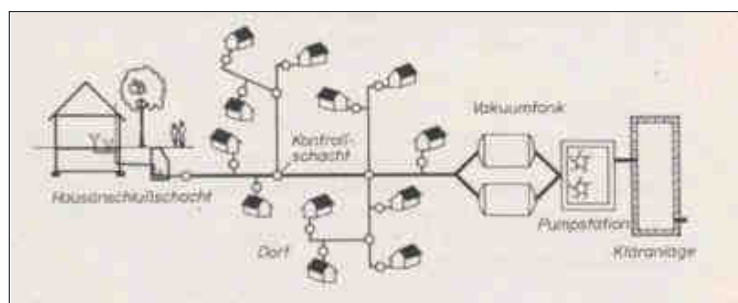


Image 1 System of the vacuum sewerage

3.0 Function of the vacuum sewerage

The vacuum pumps located in the vacuum collection station generate a vacuum level of 0.6 to 0.7 bar -compared to the atmosphere- in the vacuum tanks located in front. The vacuum continues via the pipe lines up to the domestic shafts. As soon as liquid waste accumulates in a household, a control device opens an interface valve and the liquid waste is sucked out under addition of air towards the vacuum collection station. Air and sewage get into the vacuum tanks. When the vacuum tanks are approximately half full, the sewage is removed by means of sewage pumps and led to the treatment plant for processing and purification.

4.0 State of technique

According to literature, the published draft of a working sheet of the ATV of February 1985 and own research, the vacuum sewerage is presently manufactured and operated as follows:

4.1 Pump station/ vacuum collection tanks:

Two execution means are distinguished between:

Vacuum collection station with mounting of pumps in dry position;
vacuum collection station with mounting of pumps in wet position.

4.2 Pump station with mounting of pumps in dry position

The building part consists of a substructure, made according to size and amount of the pumps and a built-on superstructure for which mostly a prefabricated garage is used.

In the superstructure the vacuum pumps, sound feeding and measuring plants, wash basin and toilets are located.

Building site of the technical outfitting

Vacuum pumps

Self-lubricating pumps have proved to be worthy that create the vacuum by means of a liquid ring. They do not require lubricating within the working space. The air which is sucked out of the vacuum tanks is blown out through a pipe above the station's roof level, which results in less odour emission. If the installation is situated at the centre of a location, the used air is led through an absorber shaft which is filled with suction and muffling materials. The condensate can drain and no further emission is noted.

Sewage pumps:

Of the numerous types on the market, those sewage pumps with a clear passage of 75 mm have proved to be the most reliable. They cause no blockages or built up of debris and they operate safely.

Vacuum tanks:

They consist of a 10 mm thick steel sheet and are protected against corrosion both inside and outside. Access and cleaning is guaranteed through a manhole.

Size and Amount of Vacuum Pumps, Sewage Pumps and Vacuum Tanks

The number and size of the vacuum pumps, sewage pumps and vacuum tanks depend on the amount of residents using the system.

The installation is chosen in a way that one vacuum pump and one sewage pump each serve one vacuum tank.

Pump stations consist of at least two vacuum tanks with the corresponding pumps. The calculated transport demand is divided to several pumps with a single capacity of 3 and 5 KW power demand in order to avoid current peaks. These pumps are bolt against another so that only one of the both pumps can run at the same time. The long term reservation costs for peak current are thus reduced to 50 %. If an installation consists of several vacuum and sewage pumps, considerable long-term reservation current costs can be saved by using a balanced control switch.

Effectivity of the pumps

Liquid ring vacuum pumps dispose of a very good effectivity as they only operate in the area up to 0.7 bar vacuum.

The current costs for the production of the necessary amount of air for transporting each cbm sewage amount to 0.15 DM or for each resident = $40 \times 0.15 \text{ DM} = 6.00 \text{ DM /year}$.

In contrary to that the sewage pumps dispose of a bad effectivity. This can mainly be explained by the fact that the suction is effected from a vacuum area of 0.6-0.7 bar that is only reduced by 0.06 bar by the static water pillar averaging to 0.6 m.

The pump costs for each cbm sewage amount to 0.30 DM or for each connected resident =

$40 \times 0.30 \text{ DM} = 12.00 \text{ DM per year}$

transport costs amount to approx. 18.00 DM per resident and year.

4.3 Pump station with mounting of the sewage pumps in wet position:

Contrary to the mounting of pumps in dry position the sewage pumps are mounted directly as submersible pumps in the vacuum tanks, that are located vertical. The equipment of the sub contraction remains like the mounting in dry position.

The pump is permanently flushed by water. It pumps from a vacuum area of 0.6 to 0.7 bar vacuum but

this area is reduced by the static pressure of the water pillar that is on average 2.0 m high in the vacuum tank so that effectively a transport from an area of 0.4 bar vacuum is effected. The pump mounted in wet position has priority. With this approximately 20 % of the transport costs of the sewage pump can be saved.

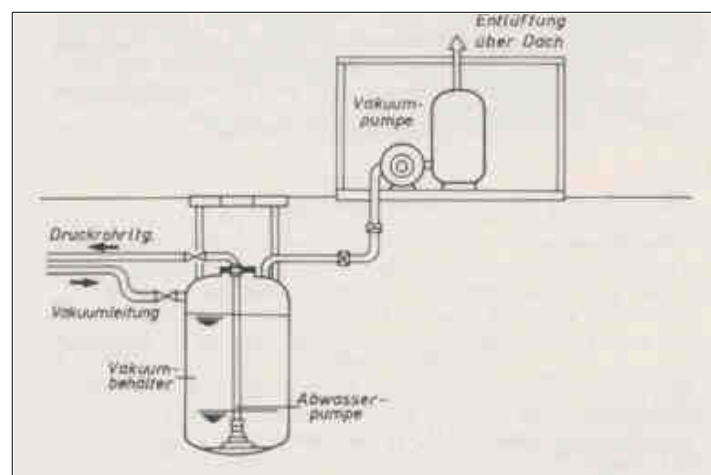


Image 2. Sewage pump in wet position

Emergency power unit

Emergency power units have been mounted into pump stations very rarely. According to the EVU's the current supply net is connected by means of even in case of a snow catastrophe in Schleswig - Holstein the longest power failure would be less than 4 hours.

Pipe net

Main and auxiliary pipes are formed in a branched way. Pipes PN 10 made of PVC with a diameter of DN 65 to DN 150 are used.

Way of bedding

The pipes are bedded in a sufficient depth to prevent freezing in winter. In order to transport the water by air a complete filling in some sections of the pipe is necessary. This results in a systematic formation of peaks and troughs which vary according to the diameter of the pipe.

Pipe revisions are located in the troughs.

They serve the determination of leakages in the pipe net and the air condition when the transport system breaks down.

4.7 Flow velocities in the pipe network

According to the vacuum pressure flow velocities of 1 and 7 m per second are measured in the short peak areas.

Blockages, sedimentation, maintenance of the network

No cases of blockages or sedimentation have ever been reported at any installations in normal operation. The network requires no maintenance.

4.9 Pressure testing of pipe network

The pipe network is checked regarding leakages. The test is considered passed if within an hour the vacuum pressure of 0.6 bar does not lose more than 10 %.

4.10 calculation procedure

So far the pipe net was dimensioned according to empirically gathered facts. There are no calculation procedures except the procedure being published in the working sheet draft of the ATV.

4.11 Interface valve at the house connection

In the cellar or in the domestic shaft an interface valve is located. It consists of a membrane valve that

is connected to a control box with 2 pipes. The liquid waste arising in the house runs down to the interface valve and blocks. Via a pitot tube it gets into the control box and causes a pressure on the located membrane. This opens and closes the suction valve via 2 control lines. It is set to a certain opening time in which the water can drain and a certain amount of air can flow in afterwards. If the pressure is reduced under 0.3 bar the valve manages during the opening phase just the water drain. But the necessary air for the transport does not flow in after that. If in that time several valves open without air coming in afterwards, the channel runs full of water and it drowns. The system breaks down. In this case the emergency stowage space being either built in the shaft or arranged on the house gets into action and stores the sewage until the re-conditioning of the system. For preventing such breakdowns air-conditioning-stations are mounted are installed at the ends of problematic, long channel ways. They shall add air via a magnet valve, prestostat or time relais when needed. Trials trying to add air together with a membrane function via a tube with adjusting cock into the channel net were not successful because an adjustment of air inlet might be possible in high vacuum areas but would then lead to a lack of sufficient air inlet in dangerous lower areas. If the adjustment is made at the lower value, too much air gets into the channel net when a high vacuum is caused and that would cost energy.

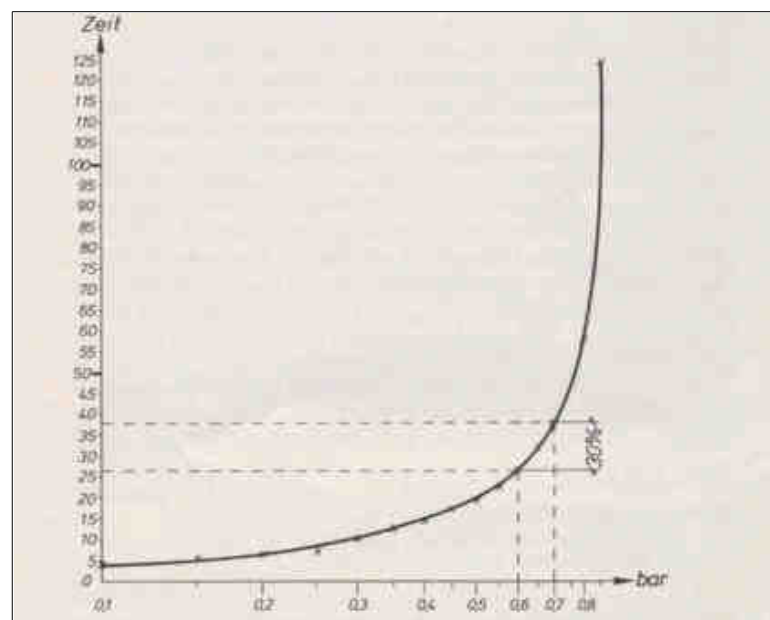
5.0 Development of a new and operation-safe transport system

5.1 General

Due to the insecurities in the present system a complete vacuum sewerage plant was built with crystal pipes. Several examinations and measurements led to entirely new findings and to the development of an operation-safe transport system. In the following you can see all details of the findings that were made in vacuum sewerage.

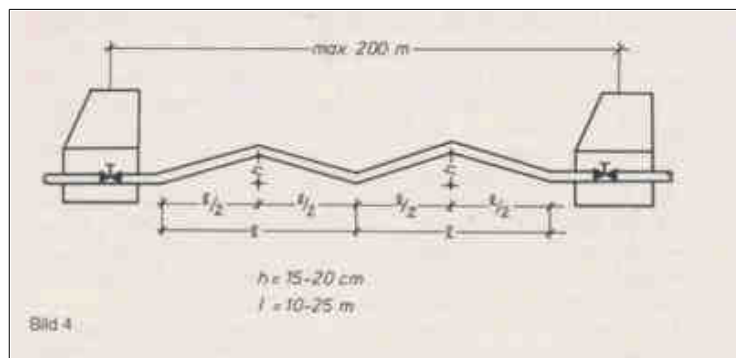
5.2 Pump station

Time / pressure diagrams (Image 3) that were taken with vacuum pump operation show an even increase of the energy needs up to a vacuum of 0.55 bar. From 0.6 bar an increasing energy demand is necessary for increasing the vacuum. Practice showed that for plants being operated with only 0.6 bar vacuum, a saving of approx. 30% of the energy costs is possible.

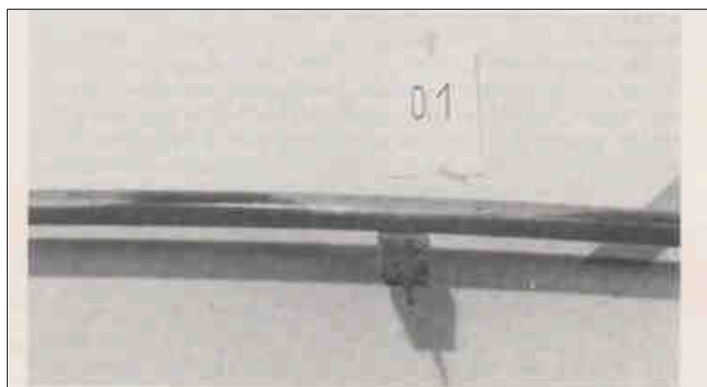


5.3 Pipe network

The most favourable way of bedding the pipes turned out to be the arrangement of peaks and troughs in regular intervals. For upgrade as well as for downgrade flow the same flow velocity of 4 - 5 m/sec. were measured.



The air could entirely be used for the transport of water. Even with a vacuum of only 0.1 bar the transport of liquid waste could be effected without problems.



5.4 Control shafts

Control shafts are arranged at junctions, but mostly at distances of 200 m from one another, in order to monitor the network. Stop valves as well as suction valves are already built into these shafts at the time of manufacture to deal with the potential problem of rainwater penetration. The network may be inspected by unflanging the connection so that access to all pipes will be permitted.



5.5 Pressure test

During a fault of the operation a considerable pressure could be put on a lower located sewage area by a higher located area and thus overstrain the pipe network more than in vacuum operation.

The leak detection of the pipes should therefore not be effected by a vacuum but with a pressure of 20 to 30 m water pillar. In this pressure area a compressed pebble bed is enough, abutments of concrete do not have to be arranged.

The pressure test will be effected by the suction valves being located in the control shafts in short distances or throughout the entire canal net.

The domestic valves do not have to be secured individually, as they are allowed for PN 10.

5.6 Domestic shaft with interface valve

Main item of the investigation was the domestic shaft with the interface valve, as in this area the greatest insecurity in the vacuum system was found.

The operation safety and construction was to fulfil the following:

For the valve:

Free penetration in order to prevent the loss of energy

opening independent from pressure

closing without extern energy

transport of sewage and at the same time adding of air, supervision and report of the operation function in the connected house

long lasting durability and no need for maintenance

For the domestic shaft:

water tightness

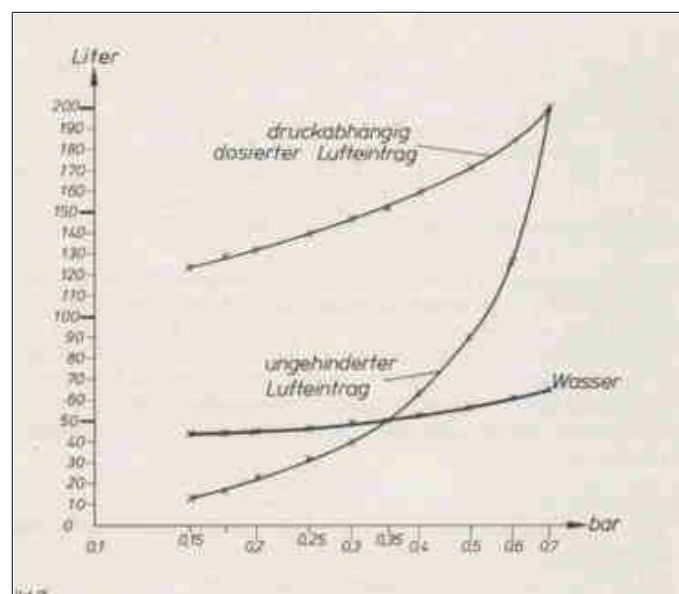
buoyancy safety

frost safety

simple mounting

Trials with valves from the market did not lead to a satisfying result. A new valve made of PVC was manufactured having the following details and functions.

The valve disposes of an inflow diameter of 50 mm and an outflow diameter of 65 mm. A Chamber for water and air is located in the middle. During admission, air flows into the chamber, becomes mixed with the liquid waste and leaves the valve as a mixture of water and air. The valve is opened hydraulically and closed by means of a steel spring at a force of approximately 400 kg.



The control device is activated electronically and requires no contact with the liquid waste. The valve function is monitored and transmitted from the shaft to the house via cable. In the event of several villages being connected, it is possible to monitor a domestic drain on a central monitor via telephone cable.

The valve was permanently tested by adding textiles, foam material, paper and sand. 200.000 (in words: two hundred thousand) connections were executed without any wear and tear being noted. It can be taken as a fact that the valve has to operate approximately 4.000 connections per year.



Valve and control are already built into the watertight concrete shaft at the manufacturer. No mounting or electronic works are necessary on the building site.

5.7 Extension of the area to be drained

According to the processing that was practiced until today an area of approx. 8 km diameter can be drained with a vacuum station. But with reduced vacuum problems occurred in the border territories. For stabilizing these zones as well as extension of the catchment area a new sewage system was developed. It consists of the vacuum main station and the higher or lower located vacuum slave position.

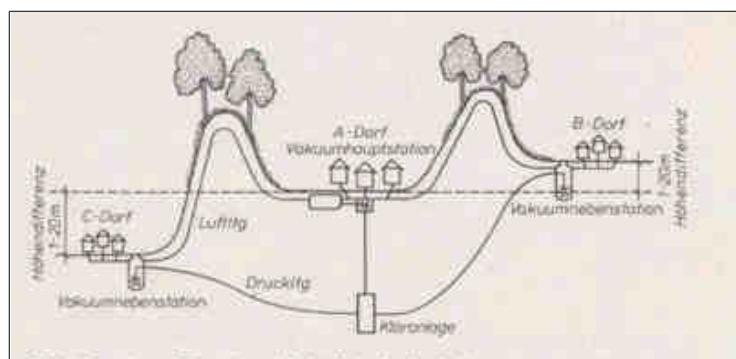


Image 9: extended catchment area of vacuum sewage
 Vacuum pumps are only present in the main station. The vacuum tanks of the slave position are connected to those of the main station with an air line so that both dispose of the same vacuum conditions. The vacuum slave position consists of an over ground mounted switchboard and a sewage pump located in a way that it is flushed by water, that transports the liquid waste via a pressure line in the sewage plant for main as well as slave position.

6.0 Amortisation rates for the vacuum sewerage

Pump station

Building part approx. 2%, machine part approx. 6-10%

Pipe net

1.25 %

Domestic shafts

Building part 2%, control plant 4%

Operation and administration

Pump costs approx. 0.45 DM each cbm sewage or 18.00 DM per inhabitant and year.

Administration costs approx. 0.25 - 0.35 DM each cbm sewage or approx. 12.00 DM per inhabitant and

year.

7.0 Manufacturing costs

The manufacturing costs vary according to the population density and the possibility of a pipe laying in berm or street.

In Lower Saxony 12 communities belonging to the same catchment area were investigated and the manufacturing costs of the vacuum sewerage with the conventional free gradient drainage were compared. The costs for the pump station, channel nets, domestic shafts and control devices were taken into account. The communities took as a fact that each inhabitant would have to make a single payment of 1,500.00 DM; the rest of the project was thought to be financed by means of the free capital market without any means of public subsidies. The free capital means were offered with 7% interest and 1% repayment. The cost calculation showed for the connection of 9639 inhabitants/population equivalent in the free gradient system total costs of 48,200,000.00 DM in the vacuum system total costs of 22,100,000.00 DM.

The economy calculation showed costs for each cbm sewage (without purification in the sewage plant) in free gradient system 9.24 DM each cbm or 370.00 DM each inhabitant/ population equivalent per year. In the vacuum system 3.07 DM each cbm or 123 per inhabitant/ population equivalent per year. When taking advantage of public subsidies - according to the rules of the land - the sewage price in the free gradient system would have been 6.27 DM per cbm or 250.00 DM per inhabitant per year, in the vacuum system 1.71 DM each cbm sewage or 68.00 DM per inhabitant and year. An investigation of 7 communities in Schleswig-Holstein showed for a number of inhabitants of 8,100 a financing on the free capital market of 7% interest and 1% repayment and a personal payment of 500.00 DM per inhabitant population equivalent in the free gradient system total costs of 14,369,000.00 and in the vacuum system of 8,747,000.00 DM. The economicalness calculation showed costs per cbm sewage (without purification in the sewage plant) in the free gradient system of 4.00 DM each cbm or 160.00 DM per inhabitant per year, in the vacuum system of 2.38 DM per cbm or 95.00 DM per inhabitant per year.

8.0 How safe is the vacuum sewerage system?

Regarding all passenger ships and aeroplanes there is no conventional sewage in the free gradient system anymore. Since decades it is done with the vacuum system without any problems. The building rules and regulations are manifested in the DIN 86281.

The development of the vacuum sewerage in the rural parts has surely not taken place without problems. According to today's findings and the state of the art it can be put on the same level of the free gradient system regarding the operation safety. It needs lower investment costs (approx. 30 - 50 % saving) for approx. the same operation costs.

9.0 Why are there so few vacuum sewerage plants built?

The plant being built in crystal pipes was visited by many authorities and engineering offices. A questioning showed that only 1% of the engineers have built vacuum sewerage plants. Approx. 35% knew a vacuum sewerage, 64% had never taken notice of such. Even two professors working in the field of sewage did not know anything about operation, function and costs of the vacuum sewerage. Another reason was mentioned which is the present occurrence of faults in the operation of several parts of the system.

10.0 How can one explain the inhabitants of the rural areas the advantages of the vacuum sewerage?

The so called ATV (special gremial for sewage) is needed for this to publish as soon as possible a detailed working sheet, in order to clarify present insecurities. But also the politicians are needed to see that the building of a vacuum sewerage plant even without public subsidies burdens the inhabitants less than the building of a free gradient system sewage with public subsidies.

Not to speak of the possibilities to open the building economy a large working area without public subsidies.

Literature:

Draft of a working sheet: vacuum sewerage, Korrespondenz Abwasser 2/85

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