# A2/ Principles of a genuine high flow waste water fitting with an in-pipe integrated ventilation

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**Abstract**

The demand for high flow capacity wastewater drainage systems is very high for sanitary and construction industries despite the known fact that high flow in drainage systems can often be related to the self-emptying of traps if the flow is not constricted to a maximum critical value. On the other hand, emptied traps can mean severe health issues as has been observed in the industry in the past. The scope of this research is to develop a new, technically optimized product which fulfils the demands of sanitary and construction industries with substantial material and labor saving advantages but without compromises on the health and other market issues.

The study has been carried out utilizing both virtual engineering (CFD) and experimental methods. The main functioning principles of the new product concept is described precisely emphasizing the scopes as well as the assumptions behind each feature in this paper. The descriptions are supported by CFD simulation results obtained under a range of working conditions. The simulations consider the multi-phase characteristics of the flow in such systems. The test results obtained in the Geberit tower are presented to show the advantages and limits of the new development as compared to other existing drainage systems. The results of a series of tests according to the European Standards display the applicability of the new concept in buildings without any malfunctioning. The new concept is validated by comparison of the results of these tests with the requirements of standards.

The new concept proves to accomplish an approximately 38% increase in capacity for a drainage stack of dimension DN100. With such an increase the drainage system reaches to its physical limit.

**Keywords**

Wastewater drainage; High-flow fitting; High-flow stack system

## 1 / Introduction

The number of high-rise buildings increases in the last decades worldwide rapidly as the technologies in building and construction industry advances. The architects, MEP planers and contractors need among others new wastewater drainage system concepts in planning such buildings since the very high competition in this industry demands cost saving compact systems which allow installations with substantially less space. Some available systems like single stack Sovent or ventilated double stack systems have provided reasonable solutions so far however any improvement of these systems will help the construction industry further to build technically and commercially better optimized buildings.

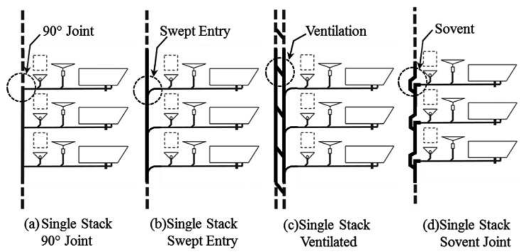


Fig. 1: Typical stack system configurations.

The single stack, single stack ventilated and single stack Sovent systems are three of the mostly utilized systems in building drainage applications. Some of the typical stack system configurations are shown in Figure 1. The type of system is selected principally based on the building size, so that the capacity of the drainage is sufficient for the building under consideration. The seal water loss by the traps connected to the system is the limiting factor which determines the allowable capacity of a stack regardless of the type of selected system. A trap which according to Standard EN12056-2 must always contain seal water at least having a height of 50mm. It is supposed that such a trap can hold wastewater gases back from inside of buildings effectively. For this reason, every sanitary discharge equipment, i.e. washbasin, bathtub, water closet (WC) etc., must always possess a trap externally or internally integrated. It is a common practice that a stack flow capacity resulting in a 50mm seal water loss is considered to be the maximum allowable capacity for that stack system.

The water level in the trap is reduced either by evaporation of water if the sanitary appliance connected to it has not been used for a long time or by the effect of under pressure generated due to flow disturbances in the drainage system. The reduction of water must never exceed a level causing a free passage in the trap so that the waste water gas can reach to the living areas of the building. As specified in the standard EN 12056-2, this limit is reached when the flowrate $Q_{max}$=4.0 ℓ/s is attained in a single stack configuration of stack pipe dimension DN100 and connected to soil and waste pipes with 90° elbows. This flowrate increases to 5.2 ℓ/s in the same system with swept entry connections to the side branches (Fig.1b). The capacity is elevated to 7.3 ℓ/s in a ventilated single stack system with swept entry connections to the soil and waste pipes (Fig.1c). A more modern building application is a single stack system connected to soil and waste pipes with Sovent type fittings (Fig.1d). It is possible to attain a capacity as much as 8 ℓ/s with such a system without any necessity to implement a supplementary ventilation piping.

These values are of course different when different sizes of stacks are considered to be implemented. In this study the stack dimension DN100 is always referred as reference since it is one of the most commonly implemented stack dimension in the building drainage systems. In this paper, the functioning principals and the main characteristics of a newly developed fitting which raises the capacity of a single stack Sovent type system significantly, well over 8 ℓ/s, without any compromises on the geometrical constraints, e.g. the size of piping system.

## 2 / Design and Testing Approaches

The development of the new fitting has been realized utilizing both virtual engineering and experimental methods. Virtual engineering (Flow Simulation Method, CFD) is preferred especially for the study of new fitting design concepts since such methods allow rapid parametrical investigations. This technique is used for instance to simulate the flow in the vicinity of Sovent junction including the side branch entry to exploit the characteristics of flow activities which are closely related to trap seal loss. A good understanding of the dominant flow mechanisms is possible by visualizing the flow in this region by means of CFD without necessitating physical prototypes.

Experimental investigations are carried out mainly for the verification of the end design according to the standard requirements and development demands. The test results of the new design as installed on a representative drainage system are also compared with those of similar systems like ventilated single stack system to exhibit the superiority and the advantages of the new design.

### 2.1 Flow simulation method (CFD) for wastewater flows

A commercial general purpose computational fluid dynamics (CFD) program is used in this study to carry out simulations of flow in the newly designed fitting. The program principally solves the equations of motion for fluids, to obtain transient, three-dimensional solutions to multi-scale, multi-physics problem in this case. The turbulent and unsteady nature of drainage flow is considered in the set-up of simulations by including the corresponding physical and numerical models in the calculation process. In addition, the multi-phase characteristics of the wastewater in the partially filled drainage system containing a large amount of air in the piping are taken into consideration. This feature of the utilized simulation technique is particularly important because the dynamics of air flow plays an important role in emptying the traps. Setting the boundary conditions at the free surface is employed for this purpose.

The CFD program uses the volume of fluid (VOF) method for numerical solution of the governing equations. The governing equations combines all the physical models needed for defining the drainage system flows. The numerical solution of these equations yields an approximate solution to the original problem however it covers all the main features of such flows precisely. Detailed information about the formulation and the solution procedure of the technique used in this study is provided in reference [9].

### 2.2 Experimental methods

The tests have been conducted in the high tower test stand of Geberit Labs, which allows the installation of a 24m high 8 story stack composed of Sovent fittings and combined with soil and waste piping. The distance between the stories is 2.65m except the bottom story where the height increases to 3.31m. The main stack is made of DN100 size PE-pipe. A sketch displaying the overall configuration of the piping system in the test tower is given in Figure 2. In the tests of cases single stack 90° and swept entry joints the Sovent fittings indicated in Figure 2 are replaced with these joints in the same test stack.

The water is supplied to the stack at as many locations as necessary starting from the top level towards the bottom to reach the required test flowrate. At each level the flow is supplied to the stack at a maximum rate of 2.5 ℓ/s. To reach a maximum test level of the stack, 12.5 ℓ/s, the water is fed to the system at the top 5 stories as indicated in Figure 2. The tests with the stack systems considered in this paper are carried out for flowrates of 4 and 12 ℓ/s. The water feeding is adjusted to the necessary flowrate at the lowest level to come up with these values. For testing the 4 ℓ/s cases the stack is fed at the 8th story by 2.5 and at the 7th story by 1.5 ℓ/s, respectively. For testing the 12 ℓ/s cases the stack is fed at the top 4 stories from 8th to 5th by 2.5 and at the 4th story by 2.0 ℓ/s, respectively.

The measurement of seal loss has been accomplished utilizing a series of instrumented traps mounted on the side branches along the main stack at each level of the test tower. The instrumented traps are expected to loose water under the effect of pressure transients ocurring in the stack and in the soil and wastewater piping branches in a similar way to those of real drainage systems. The flush water is fed directly into the side branch pipe without the help of any sanitary appliance however experience in previous studies have proven that this type of feeding is also capable of generating pressure transients in the pipings similar to the flushings of sanitary devices as long as the feeding possesses equivalent flow conditions. It is experienced in many Geberit lab tests that a 45 second stabilized water feeding by a pump to the stack resembles the actual loading of a stack closely. Such a feeding creates testing conditions similar to actual flushing situations. In fact, this type of loading can be considered even slightly stronger than the reality. The stabilization of water feeding is reached after a 15 seconds start-up. Combined with a 15 seconds of start-up time at the beginning, a total duration of 60 seconds has been set for each case. The seal water loss is higher if the trap is exposed to a longer loading, i.e. a longer flushing time. Therefore, it is important to set not only the flow rate but also the duration time appropriately to obtain accurate seal loss results.

The pump of the tower is run up to the predetermined flow rate gradually and slowly enough so that an excessive seal loss due to start-up transients is prevented. By this quasi-stationary method, it is aimed on one hand to reach the maximum possible seal loss level on the other to achieve a high reproducibility during the tests. The time dependent behavior of flushing devices is neglected in this study assuming in is assuming that their effects are minor as compared to stack transients.

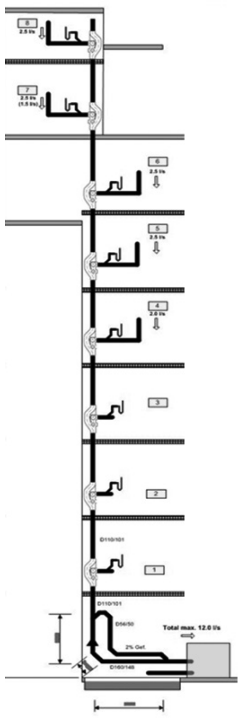


Fig. 2: An overview of the test stand.

The free end of each trap is closed where an ultrasound distance meter, a water fill pipe and an air vent are mounted. Figure 3 shows a typical instrumented measurement trap. At the beginning of each test, the traps are filled automatically up to their reference water levels. The trap water level as detected by the ultrasound meter on each trap has been recorded on a portable computer at the end of the test period. By this way it is assumed that the flow conditions, which represent those of an actual drainage system in a building are created.


Fig. 3: A typical instrumented trap to deter-mine the seal loss distribution along the stack.

## 3 / Results

The principals of designing a drainage system for a building are described in the related documents of international standards. European Standard EN 12056 is one of them listing the design rules for Europe [1]. A number of tables are provided in this standard specifying for example the proper dimensioning of piping based on the size of the drainage system needed for a building under consideration. The application range of each type of stack system is clearly indicated as well in these tables. A couple of such information have already been mentioned above in Introduction.

It is important here to mention that understanding the physics of flow mechanisms which restrict the capacity of stacks so that an optimized design of such systems totally of partially by optimizing the elements contained in these systems can be possible. It is expected to increase the capacity of a system without any need to upgrade the system to a larger dimension and without causing additional complexities through such optimizations.

### 3.1 Hydrodynamics of drainage stacks and fittings

One of the main causes of water loss in the traps is excessive turbulence generated in the stack near the side branch junctions which causes dynamic pressure pulsations at the traps. Secondly, the pressure surges appearing as a result of rapid velocity changes in the stack caused by the interruptions of air flow at the side branch junctions and/or at the elbow extending the stack to the collector pipes are responsible for excessive seal losses, i.e. emptying the traps. In Figure 4, an example of such a flow event is illustrated for a swept entry joint in a single stack system and the corresponding flowrate changes in the stack are displayed as a proof of occurrence of pressure surge in such systems. Moreover, these surges are often augmented by resonance like acoustical pressure pulses which are triggered in the stack by the surges themselves.

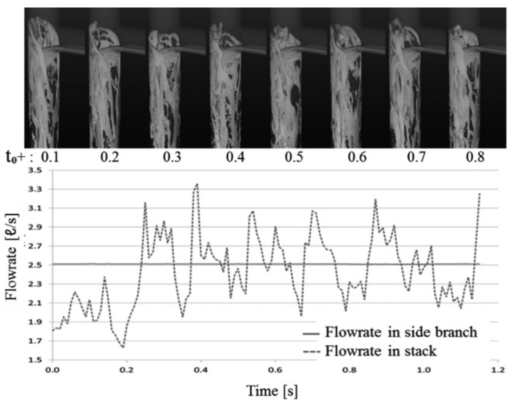


Fig. 4: A time series of photos displaying flow disturbances at the junction and the corresponding flowrate transients.

Such a coupled event worsens the effect of pressure surge on emptying the traps significantly. A waste water drainage system can be improved effectively if all of these influence factors are minimized. An advance from 90° joint to swept entry joint provides a notable improvement in the joint configuration hydraulically so that the maximum capacity of single stack DN100 system can be elevated from 4.0 to 5.2 ℓ/s. An addition of an adequate ventilation piping to a DN100 single stack system provides enough stabilization against pressure surges in the stack so that the maximum capacity of such a system can be increased from 4.0 to 7.3 ℓ/s [2-5].

**3.2 Conventional Sovent fitting**

The Sovent fitting concept as it is originally introduced to the building industry attempts to improve the hydraulic configuration of the joint and to reduce the influence of pressure surge simultaneously in the stack system. This is achieved by bypassing the side branch joint by means of the special design of Sovent as displayed in Figure 5. This configuration prevents a strong interaction of the flows on the stack and the side branch sides with each other. The water flow from the side branch piping proceeds in the direction of the stack flow before meeting it in the joint area. The two water flows have the same directions as they join together therefore they do not brake each other hence do not cause any disturbances in this critical area which can be directly transmitted to the side branch [3]. Additionally, with a proper change the direction of flow from the side branch, less turbulence is generated and only a partial termination of air column in the stack is permitted. Besides, the consequence of these positive changes in stack flow results in weaker pressure surges in the system. The maximum capacity of a Sovent stack of DN100 can reach 8.0 ℓ/s as compared to 4.0 ℓ/s of a conventional single stack system.

**3.2 High-flow Sovent fitting**

The new high flow Sovent fitting concept is based on the genuine idea of combining the advantages of both ventilated and Sovent systems in one unit. It assumed that a system with a higher allowable capacity and with better economic advantages might emerge from the combination of the functioning principles of these two present systems. The new concept should then reduce the pressure surge levels as much as possible and to separate the highly turbulent zones of the stack from the side branches as far as possible. Such a combination of effects is expected to reduce the seal water loss, and hence emptying of traps, to a minimum.

High-flow Sovent consists of two main parts as depicted in Figure 6. The first part (1) consists of a flow divider. The flow divider cuts the water film developing on the stack walls to form an open window on the outer side of the Sovent fitting as the water film approaches the first elbow of the fitting. The divider collects at the same time the film flow as a wall jet and guides it to the opposite side of the stack.

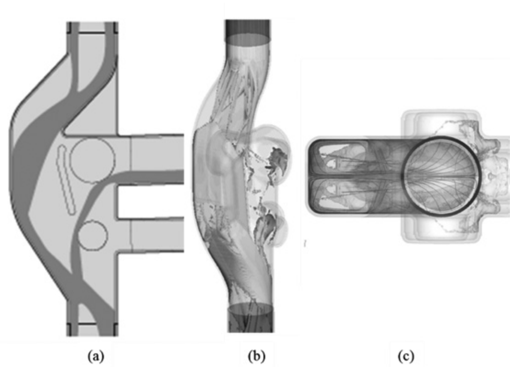


Fig. 5: A typical conventional Sovent fitting configuration with bypass flow around the joint.

The swirl zone of the Sovent high-flow fitting possesses at the immediate downstream of the flow divider an asymmetric off-set which is designed to guide the wall jet tangentially to the side wall before it proceeds further in the downstream direction. A slight rotation is created in the flow also as a consequence of this guidance. The rotation helps to keep the flow attached on the fitting wall (see Figure 6 - Top view). The special asymmetric off-set should also be positioned properly in the vertical direction in such a way that any congestion of the stack flow is avoided at the location where the side branch flow yield into the stack flow. It is worthwhile to mention here that the air- water separated layers of rotating flow is generated by means of passive asymmetric modification of the fitting body without requiring some elaborate spiral guides to be implemented inside the fitting body, as offered by others in the building industry.

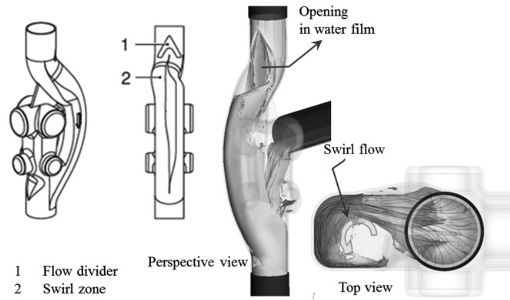


Fig. 6: The main parts and characteristics of the new Sovent high-flow fitting.

These chain of flow activities result in two separated layers of flow in the Sovent fitting. The water layer is collected to flow on the fitting walls as a rotating film whereas the air flows in a channel appearing in the centre of the fitting extending from inlet to the oulet. The air channel developing in the fitting is connected to the air channel naturally forming along the centre of the stack through the window created by the flow divider which is described above. Consequently, a continuous air channel along the whole stack system as if an invisible ventilation pipe is integrated in the centre of the stack system.

Furthermore, the rotating water film flow stays always in contact with the pipe wall which results in a constant and increased friction resistance. Besides, the water flow follows a longer streamline because of its rotational motion in the vertical direction so that an additional reduction in the terminal velocity is experienced. Both characteristics point out a hydrodynamic stabilisation of the stack flow.

In Figure 7, the special flow characteristics of the new Sovent high-flow fitting including the air channel flow is exhibited in comparison to two stacks, one consisting of a swept entry joint and the other a conventional Sovent fitting. In Figure 7(a), it is clearly observed that as the cylindrical film flow passes by the swept entry joint it is forced to totally collapse on the stack side opposite to the joint by the effect of side branch flow. This causes the air channel close and terminate at this location. A new film flow is started from this location on until it is terminated again at the same location by the next joint. Figure 7(b) displays the development of the cylindrical film flow from the stack pipe into a conventional Sovent fitting. In this case, the cylindrical film flow passing through the fitting is not forced to collapse totally and close the air channel but both the film flow and air channel is strongly disturbed in the fitting. Nevertheless, this configuration allows to reach a significantly higher capacity as compared to the former case. Figure 7(c) displays the flow characteristics of the new Sovent high-flow fitting. Here, the cylindrical film flow passes through the fitting without experiencing any appreciable disturbance. Therefore, the air channel along the centreline of the fitting does not show any collapse or closing, either. A continuous air channel extending from the inlet up to the outlet of the stack including the fitting is clearly visible in this figure.

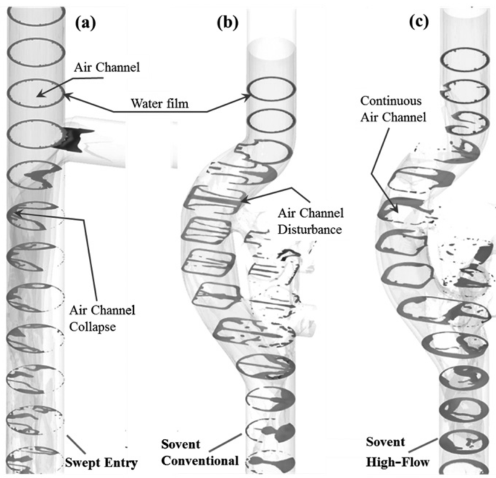


Fig. 7: Flow characteristics of a Sovent high-flow system in comparison to a conventional single stack and a conventional Sovent stack.

### 3.3 Seal loss in a drainage system with high-flow Sovent fittings

As discussed earlier in this paper, the flow conditions causing the emptying of the traps mounted on the drainage systems define the maximum capacity limits. These conditions are determined best and most directly by measuring the seal loss characteristics of the drainage systems. The seal water loss is a parameter to determine the severity of the dynamic pressure pulsations in the drainage piping systems. This method is used widely in the literature [6-8] for such purposes because of its simplicity to install and being a direct instrument indicating the level of trap water emptying. The seal water height measured given in such a study, can easily be converted into maximum suction or pumping pressure levels when it is required.

In Figure 8, seal water loss for two different stack systems are given in comparison including a reference conventional single stack system and a stack composed of new Sovent high-flow fittings. Both stack systems are of dimension DN100. The reference system is tested with a maximum flowrate of 4.0 ℓ/s which is the allowable capacity for such a system with which a seal loss level of 50mm is supposed to be reached. The Sovent high-flow system is tested for two different flowrates of 4.0 and 12.0 ℓ/s. This way, it is possible to compare the results of the new system, on one hand directly with the reference case, on the other it is possible to display the significantly higher capacity of the newly designed fitting concept as compared to any other system of the same size.

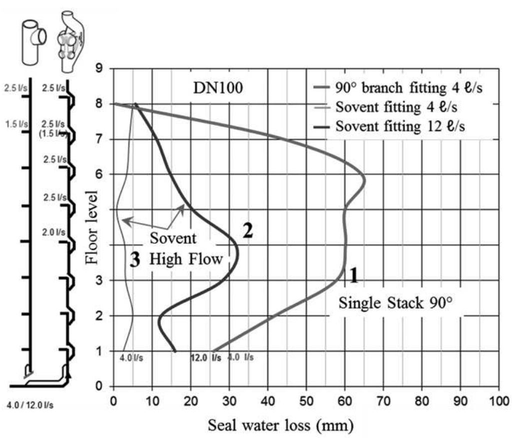


Fig. 8: Seal loss characteristics of a Sovent high-flow system in comparison a conventional single stack at the maximum capacity loadings.

As observed in Figure 8, a maximum average seal loss of ~65mm is recorded (Curve 1) in the reference case. This level is even higher than the commonly allowable 50mm for such stack systems and size. Curve 3 designates the seal loss values along the Sovent high-flow stack of this study at a flowrate of 4.0 ℓ/s. The average maximum seal loss reaches barely to a level of 5mm. This is almost a negligible seal loss level for building drainage systems. The Curve 2 depicts the seal loss distribution along the Sovent high-flow stack at a flowrate of 12.0 ℓ/s. As the flowrate is increased to this capacity, the seal loss increases to a maximum average level of ~32mm. Despite a significant increase in the capacity, only a moderate increase is observed in the seal loss level which is still well below 50mm allowable limit. It is noteworthy to mention here that there is theoretically still enough potential in the new Sovent system to increase the flowrate range further. However, Geberit specifies the upper limit of the new system as 12.0 ℓ/s for DN100 because the study of all technical risks of high-flow systems more than 12.0 ℓ/s in combination with other sanitary appliances contained in such systems remain open.

## 4 / Conclusions

In this paper, it is reported on the main characteristics of a new high-flow Sovent concept which is capable of elevating the capacity of wastewater discharge systems in buildings significantly over the presently available systems. The hydrodynamic features of the concept are described in detail based on the results of some CFD simulations and extensive experimental investigations. The results obtained with the new fittings are always verified by comparisons with those of a well-known reference system as well as with those of some commonly installed systems in today's buildings.

It is shown in this paper that the new Sovent high-flow fitting increases the maximum attainable capacity of a discharge stack as much as 40% by combining the positive features of externally ventilated and conventional Sovent systems. The maximum capacity of a discharge stack fitted with Sovent high-flow fittings of dimension DN100 extends well over 12.0 ℓ/s. Moreover, this increase is achieved without upgrading the piping dimension of the high-flow fitting to a larger size than the present conventional fittings.

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