

A NEW SELF-CLEANSING SCREEN FOR USE WITH HYDRODYNAMIC SEPARATORS FOR CSO TREATMENT

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ABSTRACT

The focus of urban drainage in the 90's has shifted from the need to provide structurally sound drainage systems with adequate hydraulic carrying capacity to water quality issues and the need to achieve use related water quality standards in receiving water bodies.

Hydrodynamic separators have successfully been used as effective high rate solids liquids separation devices to control water quality at Combined Sewer Overflows (CSOs) and at wastewater treatment works (Andoh and Harper, 1994; Andoh et al, 1996).

This paper describes a new generation of separators with an integral self-cleansing screening system termed the Hydro Swirl-Cleanse™. This system ensures the removal of all material larger than a specified aperture size, eg. 4 or 6 mm. The development of the technology and the principle of its operation are described and results of independent testing of a prototype confirming compliance with intermittent discharge requirements are presented. The paper sets the recent developments in the context of integrated systems for alleviating the problems within drainage systems.

It is concluded that the device complies with the requirements for 6 mm solids separation. Work is currently underway to retrofit the technology to existing conventional CSO chamber designs.

KEYWORDS

hydrodynamic separation, combined sewer overflow, screening, water quality.

INTRODUCTION

The majority of investment required to ensure that waste water treatment works in the UK are compliant with their current consent standards has now been completed. The emphasis for capital investment has shifted towards reducing the polluting impact of discharges from overloaded drainage systems. This requirement of the Urban Waste Water Directive has been addressed by the former National Rivers Authority (now Environment Agency) Asset Management Plan (2) (AMP2) Guidelines (1993) which provide a policy statement for tackling the problem in England and Wales. The Guidelines note that there are about 25,000 identified CSOs in the UK of which about one third are unsatisfactory. The Regulatory Body adopted the approach of recognising water quality objectives and linking these to the amenity value of the receiving watercourse. Emission standards for intermittent discharges to the different categories of water course are given. The highest standard for intermittent discharge from CSOs requires "separation, from the effluent, of a significant quantity of persistent material and faecal / organic solids greater than 6 mm in any two dimensions." All discharges to the environment require a legally enforceable, formal consent, issued by the Regulator. It is apparent that the water companies will propose CSO devices that, as a minimum, meet this standard.

Hydrodynamic separators have been used since the 1960's when they were pioneered by Bernard Smisson. Their operation and effectiveness is well documented (Hedges et al, 1993; Boner et al, 1993; Andoh and Smisson, 1994; Andoh et al, 1996). Smisson was motivated in his research to develop “*a device which could concentrate sewage into a portion of the water used as a carrier.*” This device could then be used at strategic locations on overloaded sewerage systems to provide a “*certain amount of treatment to water discharged to watercourses with a consequent improvement in the condition of streams, rivers and other receiving waters*” (Smisson, 1967).

There are currently over 180 Hydro Storm King® CSO installations in the UK. They have principally been designed to remove the heavy, settleable, polluting load in line with Smisson’s original objective for a CSO. Since hydrodynamic separators were first developed for use in reducing the pollution caused by storm water overflows, they have subsequently been refined to trap and retain floatable material. In a previous study a mean solids removal efficiency of 78% of the inflow solids was recorded for this type of device (Lole and Williams, 1993) compared with a mean removal of 52% for a mechanically raked 6 mm bar screen (Meeds and Balmforth, 1995). In common with conventional CSO chambers such as stilling ponds and high-sided weirs, hydrodynamic separators are also less effective at preventing the discharge of neutrally buoyant material within the main body of the flow. It is the persistent, inorganic material that causes the “aesthetic” pollution of water courses and gives rise to most of the complaints from the public (FR 304E, 1988).

The Swirl-Cleanse™ system has been developed in response to the need for a low maintenance screening system that requires no external power supply. The Swirl-Cleanse™ system in combination with hydrodynamic separation ensures that the sinking and floating material as well as the neutrally buoyant “aesthetic material” are removed from the flow.

THE HYDRO STORM KING® OVERFLOW WITH SWIRL-CLEANSE™ SYSTEM

The basic flow pattern and principle of operation is as follows: flow enters the main body of the Storm King® and undergoes hydrodynamic separation whereby the settleable and gross solids are removed in the underflow from the unit. The internal flow patterns and the effect on settlement of the configuration of the internal components has been described elsewhere (Andoh and Smisson, 1994; Harwood and Saul, 1996).

The flow then passes upwards between a series of baffles which reduces its speed of rotation before it weirs over and through a conical screen on which the neutrally buoyant solids are deposited as shown in Figure 1.

The screened water is initially prevented from being discharged by a level control device. In this illustration the level control is shown as a tipping gate but alternatively a self-priming syphon may be used. The function of this device is to act as an open or closed valve and thus cause the water level to rise in the chamber. Once the rising water level has reached the apex of the screen it removes deposited material in three ways:

1. The rise in water level increases the air pressure under the screen “blowing” air through the screen holes. This effect becomes more pronounced as the water level rises and air is forced out from beneath a curtain of water. This mechanism is useful for cleaning the top perimeter of the screen which is continually covered in water and would otherwise blind.
2. The water rising back up through the screen lifts material off the screen. The relatively low open area of the screen holes (22% for a 4 mm screen and 27% for a 6 mm screen) has the effect of increasing the pressure and thus velocity at which the water passes through the screen.
3. The central waste pipe acts like the plug hole in a bath and a vortex is set up which spreads around the surface of the screen. This vortex has a scouring effect on the debris but in addition it helps to carry it towards the central waste pipe by secondary flow effects.

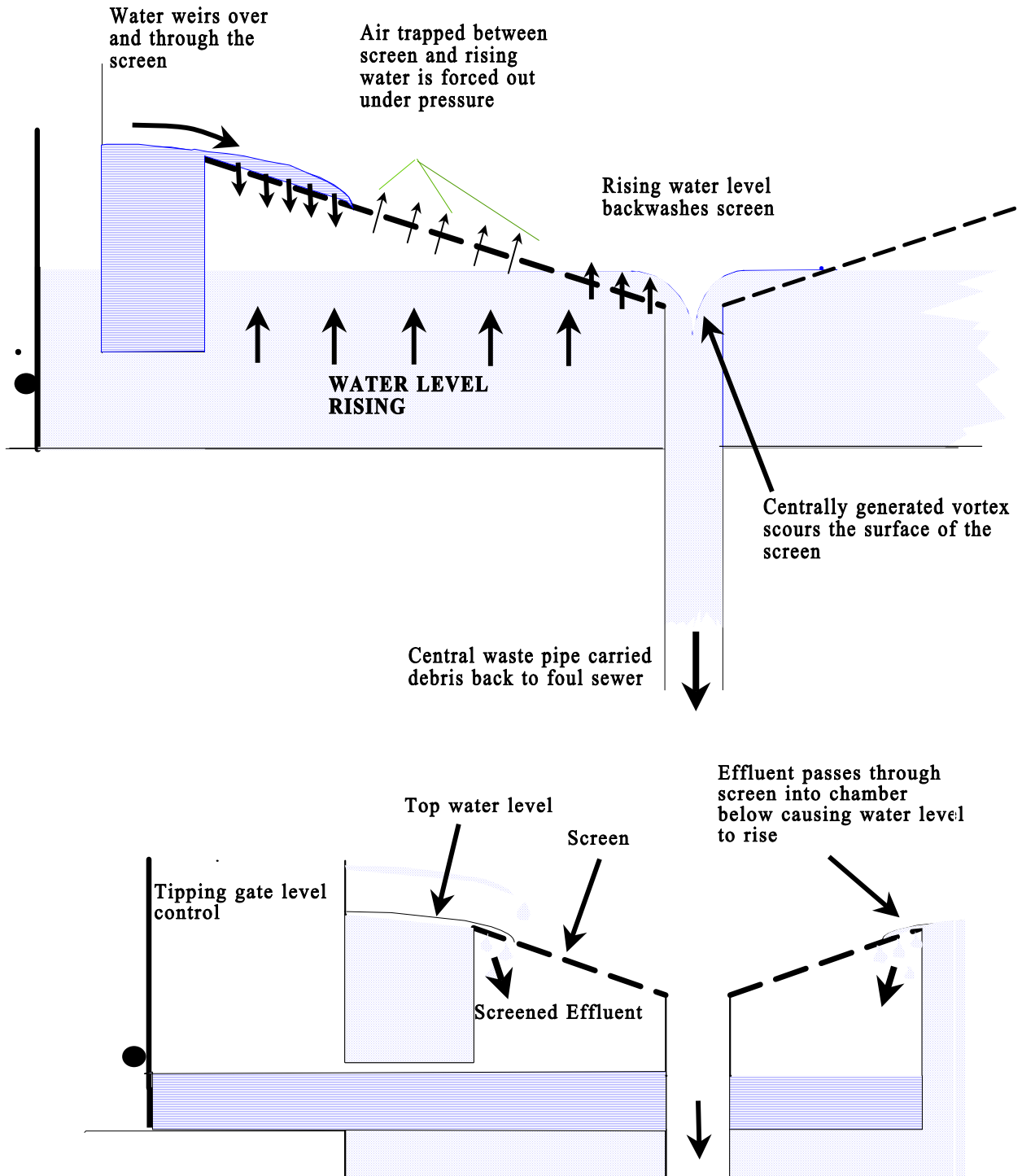


Figure 2 Screen cleansing mechanisms

These three cleansing components are illustrated in Figure 2.

The angle of the cone is important in optimizing this cleansing effect. If it is too steep then the scour of the swirl does not affect the whole of the screen and the required range of the back wash will be high on a unit that is several metres in diameter. If it is too shallow however the debris is not easily carried to the central waste pipe and can remain on the screen for several back wash cycles. A series of screens with angles of between 5° and 20° were built to determine which was the optimum.

The flow down the central waste pipe is an important component of the self-cleansing process: As this flow fills the pipe a vortex is generated which radiates outwards over the diameter of the screen. If there is no flow down the central pipe then no vortex is initiated. The vortex is responsible for dragging the debris

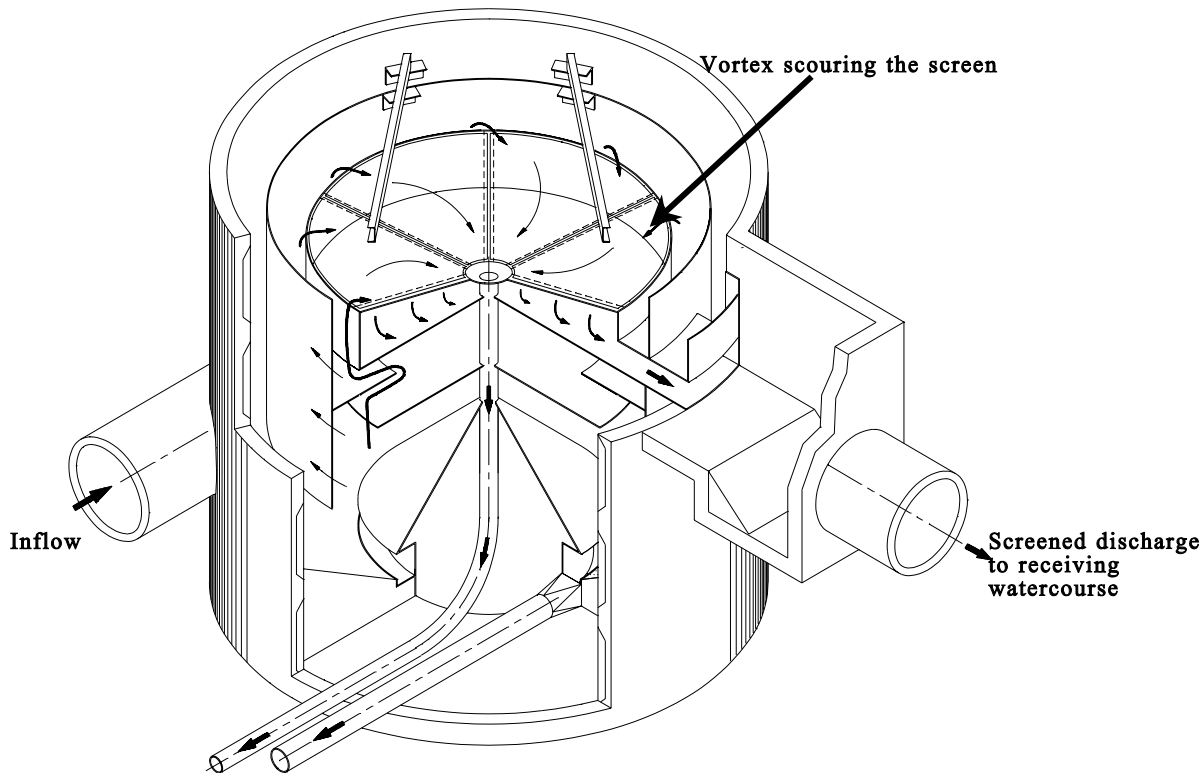
away from the screen, into the main body of the flow and down the central waste pipe. At peak design loading with crude sewage, this mechanism has been found to be necessary to ensure that the screen remains clean.

Once the water level has risen to the top of the screen the backwash is complete. At this stage the gate tips over (or the syphon primes) discharging screened effluent to the receiving water course. The water level within the chamber drops to just below the apex of the screen at which point the gate closes (or the syphon breaks) and the cycle repeats itself.

FULL SCALE TESTING

After developing and testing the Swirl-Cleanse™ mechanism on a 1.5 m diameter unit the next stage was full scale prototype testing of a more typical production size unit. A 3.4 m diameter Storm King® with Swirl-Cleanse™ was fabricated for testing and evaluation at the UK National CSO test facility. This unit was designed to handle flows of up to 200 l/s. Figure 3 illustrates the arrangements of the internal components and the exit spillway into which the tipping gate or syphon level control device is fitted. Efficiency testing was carried out by Professor A Saul and R Harwood from Sheffield University. A range of inflow rates and underflow (pass-on to treatment) rates were used including hydrographs simulating a 50% peakedness summer storm and a 10% peakedness winter event.

Material was collected from the outflow streams using net sacks with a 4 mm mesh size. These were left to drain for 30 minutes after each test prior to weighing. A full description of the test facility, procedures used and results was given by (Harwood and Saul, 1996). The key objective of this testing work however was to validate the Swirl-Cleanse™ process and find whether it was able to keep a 6 mm aperture screen free from blinding when fed with crude sewage.



Continuation flow to treatment

Figure 3 Hydro Storm King® Overflow with Hydro Swirl-Cleanse™

RESULTS AND DISCUSSION

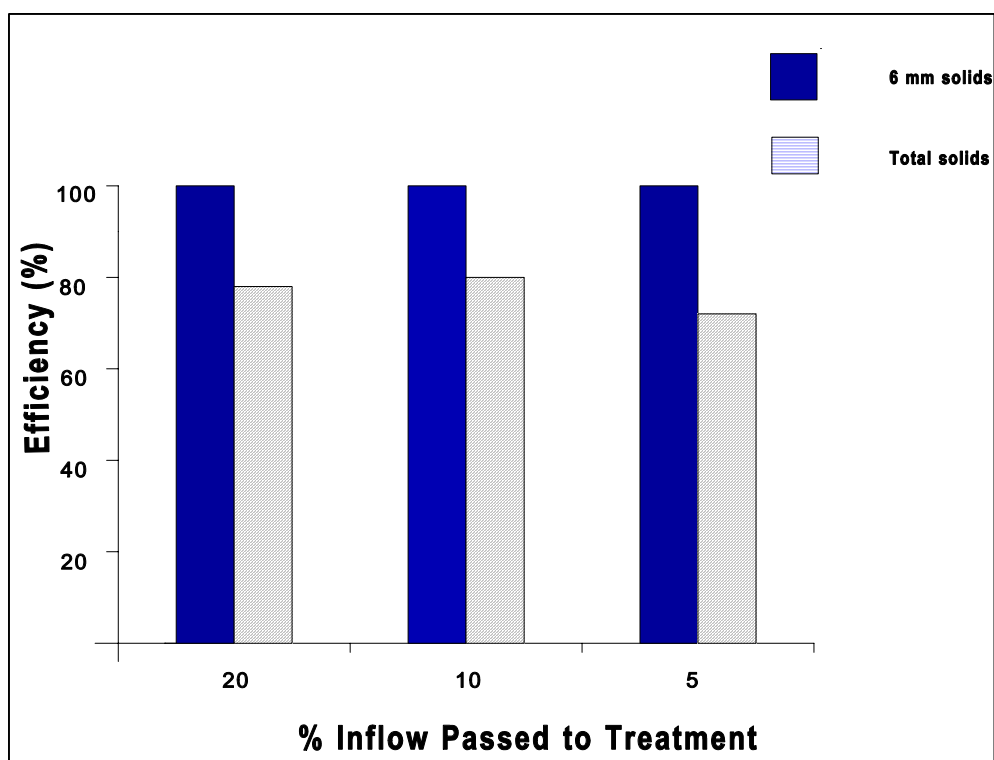


Figure 4 Efficiency of the Swirl-Cleanse™ system at the design inflow rate of 200 l/s

The results of the test at the design inflow rate of 200 l/s are shown in Figure 4. The 3.4 m unit was found to handle flows of up to 250 l/s before the tipping gate mechanism was flooded. For the particular gate design trialled, the Swirl-Cleanse™ process was effective in keeping the screen clean between flows of 50 l/s and 250 l/s. Below 50 l/s it was found that the flow was insufficient to cause the gate to operate. When operating in this condition (ie. without backwashing), the screen had partially blinded after an hour with complete blinding taking 3 hours and 10 minutes. The unit, however, self-cleansed when flows increased and the backwash mechanism came into operation. Over the duration of the testing period, the unit was subjected to an equivalent year of typical CSO operation and at no time was it necessary to clean the screen manually.

The backwash frequency was at its lowest at the minimum and maximum inflow rates. Based on this experience, albeit operating with a concentrated crude sewage, a peak backwash frequency of once every 20 seconds at design flow rate appears to be ideal.

At the minimum flow rate, the chamber below the screen filled slowly but when the gate tipped and released the screened effluent the level dropped quickly and the gate would close. At the maximum flow rate the chamber filled quickly but the high inflow rate meant that once the gate had tipped, the water level dropped slowly. The ideal cleaning frequency will depend on the characteristics of the waste water: If there is a large amount of debris in the flow the screen will block with material and a more frequent backwash will be required. The frequency of operation can be tailored to the requirements of the particular site by changing the volume of the chamber and thus affecting the time taken for it to fill.

The efficiency of the backwash has been found to be related to its upwards velocity and thus the level control device should spend as little time as possible slowing down and speeding up the discharge flow. The tipping gate therefore comes close to this ideal by opening and closing rapidly. Most of the operating cycle time is spent in either the open or closed positions.

The cleansing mechanisms themselves performed well despite the increase in the depth of water over the perimeter of the unit when compared with the small scale prototype. The scouring action of the vortex and the "air cleanse" preceding the water back wash both appeared more vigorous on the full scale unit when running at design flows. At low flow rates all three cleansing mechanisms are reduced in their effectiveness although the rate at which material is being deposited is much lower. At these low loading rates the hydrodynamic separation occurring within the body of the unit is also more efficient, thus ensuring more material is removed in the underflow. The hydrodynamic separator can be utilised as an efficient, low foot-print, primary treatment device when used at the correct loading rate (Andoh et al, 1996). In combination with the Swirl-Cleanse™ process hydrodynamic separation offers a method for removing both settleable and neutrally buoyant material within an integrated package.

CONCLUDING REMARKS

Traditionally, techniques for reducing the polluting impact of CSO discharges have focussed on providing additional storage to prevent or reduce the frequency of these discharge events. Providing large volumes of storage is a costly and disruptive solution that may be impractical. By using the Storm King® Overflow, the polluting impact of the first foul flush is greatly reduced (Lole and Williams, 1993). A significant proportion of the solids load and its associated BOD is removed by hydrodynamic separation. Screening within the Swirl-Cleanse™ system is used to remove aesthetic material.

CONCLUSION

- The Swirl-Cleanse™ system has been shown to be an effective process for screening crude sewage through an aperture screen and preventing the screen from blinding. No external power source is required other than the hydraulic head present within the system.
- Over the duration of the testing period the unit was subjected to an equivalent year of typical CSO operation and at no time was it necessary to clean the screen manually.
- All discharged effluent was first passed through a screen with an aperture size of 6 mm screen even when the unit was operated at a flow rate below that required to cause the backwash mechanism to function.
- The hydrodynamic separator in combination with the Swirl-Cleanse™ offers a possible treatment system that can be used as a low foot print primary treatment device with a built in system for removal of floatable and neutrally buoyant material.
- Used at higher loading rates the Storm King® with Swirl-Cleanse™ is a high performance CSO device which offers suspended solids and related BOD reduction coupled with screening to 6 mm or 4 mm (if required) in two dimensions.

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