Why are My Filters Failing? Forensic Analysis of Filter Underdrain Failures at WSSC’s 285 MGD Potomac Water Filtration Plant

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WSSC’s 285 MGD Potomac Water Filtration Plant (WFP) experienced catastrophic failures of the underdrains at 14 of their 32 filters, and most of the other filters showed signs of pending failure. WSSC needed to know why the filters failed, and a solution that avoided the problem in the future.

The failed underdrain systems are polyethylene underdrains fitted with gravel-less, integrated media support caps (aka IMS caps).

The IMS caps were made using sintered plastic beads.
ANCHORED FLUME BLOCK

CLEARWELL

TYPICAL FILTER CROSS SECTION

WATER LEVEL
BACKWASH TROUGH
FILTER MEDIA
UNDERDRAIN (FILTER BLOCKS) SUPPORTS THE FILTER MEDIA, AND CONVEYS FILTERED WATER TO THE FLUME

FLUME

FLUME
Existing (Former) Underdrain ("Filter Block")
POTOMAC WFP

Filter Failure History

Filter underdrain failures in each of past 10 years

18 reported failure occurrences
14 first time failures;
4 repeat failures

3 filter underdrains replaced by manufacturer
One failed a second time

4 filters repaired
Three of which failed a second time
“Catastrophic failures” refer to the underdrain blocks heaving up off the floor of the filter box.
POTOMAC WFP FILTER #5

Catastrophic Underdrain Failures

Uplift at Filter #5 involved failure of 3/8” steel rods at flume opening, and separation of filter blocks from the grout.

Grout fully separated from plastic block
INITIAL “FORENSIC” OBSERVATIONS

- Most failures were one block away from the flume, and therefore were not restrained
- IMS caps stayed in place, although a few were cracked
- Grout quality varies substantially
Similar underdrain failures were attributed to biological growths and “EPS” substances clogging the IMS caps.

Similar underdrain failures were attributed to backwash water (uplift force) in flume getting past flume block and under the un-restrained filter blocks.

Some failures were attributed to uncontrolled air in the underdrain.

Several reports of excessive amounts of filter sand accumulating in the IMS caps.

- IMS cap pores are large enough to allow sand in, but designed for sand to blow-out during backwash.
**Step 2: Detailed Investigations**

**FORENSICS ANALYSIS**

**Search for Root Causes of Underdrain Failures**

**Why and Why Now?**

- Visual inspection of failed underdrains, and observation of trends related to location of uplifted blocks (relative to flume and restraining rods) grout condition
- Review of historical operations data (filter run time and headloss, backwash pressure, etc.) to discern trends in filter performance
- Comparison of Leopold IMS caps with caps by other manufacturers, to assess potential for manufacturing differences
- Analyze IMS Caps using Electron Transmission Microscopy to determine the chemical constituents of organic and inorganic matter inside the caps
- Search for potential sources of uncontrolled air entry into underdrains
Leopold IMS caps were retrieved from Filters #26 and #17

- Potomac WFP Leopold caps (below) compared to similar products manufactured by Porex and Genpore
- Cap samples submitted to MVA Scientific for microscopy analysis
COMPARISON OF IMS CAPS

Leopold sintered bead caps showed “glazing” and extensive occlusion on bottom face (manufacturing defects)
COMPARISON OF IMS CAPS

Other manufacturers (Porex) of sintered bed caps showed uniformity in the top and bottom surface.
Pore spaces in Potomac WFP’s IMS caps found to be substantially occluded by penetrating sand and anthracite media, and a fine brown particulate coating.
SEM-EDS (scanning electron microscopy-energy dispersive x-ray spectrometry) analysis of a sub-sample of the fine brown particulate revealed silicates (sand), calcium, manganese and aluminum.
Confirmed presence of inorganic foulants:

- Silicates (sand)
- Ca, Mg, Mn (raw water)
- Al and Fe (coagulants)
MICROSCOPIC ANALYSIS OF IMS CAPS

Magnified image of sintered beads (IMS cap)

White precipitate found near top face of some caps
Material determined to be calcium carbonate

Precipitation likely caused by substantial pressure loss during flow through occluded caps
IMS CAP TESTING

Findings

No evidence of remaining biological foulants

Occasional diatoms were observed in electron microscopy images
Poor quality grout observed in a few filters (Filter #21 shown at right)

Competent grout was found in nearly all the other failed filters

- However, grout separated from plastic underdrains in all failed filters
DETAILED FORENSICS
OPERATIONAL PERFORMANCE
Trend of Increasing Filter Headloss at Potomac WFP

Headloss ≈3' when new

Air binding starts at 9' headloss

Loss of Head Reading  Exceeded Max Reading
Filter headloss has been increasing since before 2008

All filters are losing hydraulic capacity, gradually at first, and then more rapidly

As headloss increases to about 9 feet, air binding occurs, rapidly increasing headloss, reducing filter run times and water production

Air under negative pressure accumulates in the flume, then gets expelled in an uncontrolled fashion during backwash

Increased filter headloss caused increased uplift during backwash
VIDEO CLIPS SHOW RESULT OF EXCESSIVE HEADLOSS
Backwash System Investigations

Two phenomenon introduced air into the underdrains

- Recent piping modifications allowed air into the backwash header
- Filter box vents allowed air into the flume and underdrain due to excessive head loss

Installed two pressure transmitters on backwash line, and monitored for several months

Did **not** detect substantial transient spiking
CONCLUSIONS
FROM FORENSIC ANALYSIS

It is reasonable to conclude that...

Failures are the result of manufacturing defects as the root cause, which allow the embedment of sand, and over time, diminishes the porosity of the caps

All filters have lost hydraulic capacity, gradually at first, and then more rapidly

As headloss increases, calcium carbonate can precipitate and has further fouled some caps

As headloss even further increases, air binding occurs, reducing filter run times and water production

The air in the flume gets expelled during backwash, but the uncontrolled nature of the air release could further contribute to filter failures
CONCLUSIONS FROM FORENSIC ANALYSIS

It is reasonable to conclude that...

- Backwash pressure, which is now measured continuously, exceeded the uplift design condition, contributing to the failures.

- Inconsistent grout quality and poor adherence to the plastic blocks impairs the ability of the underdrain to resist uplift, and allows uplift pressure to be applied to the unanchored blocks beyond the flume.

- Introduction of uncontrolled air during backwash may increase uplift dynamics.

  *Recent controls changes appears to have resolved this issue*

- It is likely that all the “Leopold” filters will experience conditions outside the basis for design within the next few years.

- The best course of action is to replace the underdrains as soon as possible.
CURRENT SITUATION

WSSC implemented recommended operational changes and minimized additional failures during past year

WSSC has rebuilt all of the failed filters (16 rebuilt to date) on an accelerated schedule, using new stainless steel slotted underdrains

- All laterals are bolted to floor
- Minimal reliance on grout
- Slots designed to avoid clogging
- The remaining filters will be rebuilt in the next year.
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