Low Velocities in Force Mains: Impacts and Solutions

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Low Velocities in Force Mains (FMs): Presentation Outline

- Overview
- Complications and consequences
- Contributing factors
- Standards and engineering practice
- Design and O&M solutions
- Case studies
- Conclusion
- Questions
Overview: Low Velocity in Force Mains

Primary Concerns:
1. Solids deposition
2. Gas pocket accumulation (incl. air binding)
3. Grease / Biofilm accumulation

Which can lead to:
- Pipe deterioration
- Reduced asset life
- Increased life-cycle cost
Overview: Solid-liquid Horizontal Flow Behavior

Behavior is dependent on fluid properties, velocity, particle sizes, density, etc.

- **Homogeneous suspension**: Particles are uniformly suspended and move at the same velocity as the fluid.

- **Heterogeneous suspension**: A concentration gradient exists within the pipe as coarse particles move slower and begin to settle.
Overview: Solid-liquid Horizontal Flow Behavior

Heterogeneous flow can lead to solids deposition ("saltation regime")

Particles travel in discontinuous movements or by sliding/rolling along the bottom, if at all.

- Sliding bed
- Stationary bed
Overview: Solid-liquid Horizontal Flow Behavior

A sliding bed can cause abrasion of the pipe invert. Stationary beds reduce available pipe cross-sectional area.

Goal: Operate at adequate velocity to achieve heterogeneous suspension without solids deposition
Overview: Gas pocket accumulation (air binding)

Sewer gas can come out of solution within a FM and accumulate causing:

1. Reduction in pipe cross-sectional area (increases pumping head)

2. Pipe corrosion from H_{2}S attack
Additional Complications from Low Velocity in Force Mains

In addition to solids deposition and accumulation of gas pockets, other complications may include:

- Grease / biofilm accumulation
- Microbial activity, $\text{H}_2\text{S}$, odorous and corrosive conditions
Common Consequences Associated with Low Velocity in FMss

Potential consequences:

- Increased system head losses due to reduced cross-sectional area (smaller ID) and higher roughness factor

- Increased operating pressure (pump seals, piping, valves, and other appurtenances)

- Reduced pumping capacity
Potential consequences (cont.):

- Increased odor and corrosion within the FM and downstream sewers and MHs

- Pipe abrasion (sliding bed or H2S attack)

- Increased O&M costs (e.g. electrical use, chemical use, cleaning costs, etc.)

- Reduced asset life
Additional Considerations (designers)

Hazen-William’s equation is only valid in “transition zone”—not at velocity or diameter extremes

(Moody chart)
Contributing Factors

Circumstances that may lead to low velocity:

- Small PSs with 4” FMs (80 gpm = ~2 fps)
- Existing FMs reused for smaller PSs
- Manifolded FMs serving multiple pump stations
- Systems with no / low initial contributing flow (incl. phased developments)
- High wet-weather / average flow ratio
- High TDH (long FM or static head)
Contributing Factors

Circumstances that may lead to low velocity:

- PS down-sizing or other system changes
- Wear of pump components (impellers, volutes, etc.)
- Accumulation of gas pockets (air binding) in FM
- Increased system headlosses:
  - Grease accumulation
  - Biofilm growth resulting from use of ammonium calcium nitrate or certain other chemicals for odor and corrosion control in a long FM
  - FM relocations (e.g. add length and fittings)
Standards and Engineering Practice for Force Main Velocity

What Velocity is not “Low Velocity”? 
Ten States Standards (2004 ed.)¹:  
“At design pumping rates, a cleansing velocity of at least 2.0 ft/s should be maintained.”

Pumping Station Design, (3rd ed.)³:  
“The lowest design velocity … for raw wastewater is 2 ft/s to keep grit moving, and a peak daily velocity of 3.5 ft/s is desirable to resuspend settled solids.”

“Velocities as low as 1.6 ft/s are tolerable with two daily flushes.”

“If velocities are <2.5 ft/s, a daily flush at 4.0 ft/s long enough to sweep out the entire volume … is desirable.”
Standards and Engineering Practice for Force Main Velocity

_Piping Handbook (7th ed.)^2:_

“It is common practice to design sanitary sewers … to provide for velocities of 2 ft/s …. Storm sewers are commonly designed for a minimum full-flow velocity of 3 ft/s in order to resuspend sediment ….”

USEPA, “Wastewater Technology Fact Sheet: Sewers, Force Main” (2000)^4:

“Force mains … are typically designed for velocities between 2 to 8 ft/s.”
“Velocity criteria for force mains are based on the fact that suspended organic solids do not settle out at a velocity $\geq 2.0$ fps. Solids will settle at velocities $<1.0$ fps …. However, a velocity of $2.5$ to $3.5$ fps is generally adequate to resuspend and flush the solids from the line.”

“[For large pumping stations] it will generally be sufficient to design for velocities of $0.5$ up to $7.0$ or $8.0$ fps.”
Standards and Engineering Practice for Force Main Velocity

Although general consensus is >~2.0 ft/s to prevent deposition and ~3.5 ft/s to resuspend solids, application varies between designers and projects:

- Adjustable-speed pumps
- Multiple-pump systems
- Shared / manifol ded force mains
- Frequency of cleansing / scouring
Table B-9, *Pumping Station Design, 3rd ed.*³:

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Velocities Required to Scour Air Pockets from Pipelines.
Design Engineering Solutions:

- Proper hydraulic evaluation, incl. maintaining minimum velocity $\geq 2$ ft/s whenever possible
- Evaluation of alternate alignments and profiles
- Consideration of parallel pipes (if wide flow range)
- Proper air valve selection—incl. avoiding air valves wherever feasible by avoiding intermediate high points and/or achieving air-scouring velocity
- Proper odor / corrosion control measures
Design Engineering Solutions:

- Proper pump and impeller selection
- Evaluation of constant- vs. adjustable-speed pumps
- Appropriate pump controls—e.g. auto-flushing
- Consideration of screening and grit removal
  - Reducing amount of solids—esp. grit and other large particles—can reduce the required cleansing velocity
- Consideration of flushing and/or pig-launching and retrieval connections
Operation and Maintenance (O&M) Solutions

- Regular flushing at higher velocity (auto or manual)

- Maintain pumps to preserve original pumping capacity—debris-free, proper clearances, no blowby

- Refurbish or replace impellers as needed to maintain design (or higher) pumping capacity

- Change pump controls
Operation and Maintenance (O&M) Solutions

- Chemical “shocking” to kill biofilm growth
- Mechanical Pipe Cleaning (e.g. pigging)
- Odor / corrosion control chemical
Operation and Maintenance (O&M) Solutions

ICE PIGGING by Utility Service Group – Atlanta
(currently up to 24-inch diameter)

http://www.utilityservice.com/icepigging.html
Case Study 1 – Bromley & Taylorsport (Manifolded Force Mains)

- **Taylorsport PS**
  - L: 15’
  - ID: 16.54”
  - C: 120
- **Bromley PS**
  - L: 19,723’
  - ID: 48”
  - C: 90
- **Dry Creek WWTP**
  - L: 4900’
  - ID: 48”
  - C: 110

Station Discharge Piping Length and Pipe ID Varies
“C” Factor: 110

Portion with low velocity
Case Study 1 – Bromley & Taylorsport (Manifolded Force Mains)

Portion with low C-factor
Case Study 2 – Gunpowder & Burlington (Manifolded Force Main)

Discharge

Length: 17,200’
Pipe ID: 24.94”
Hazen and Williams
“C” Factor: 100

L: 949’
ID: 16.72”
C: 130

Burlington PS

L: 6414’
ID: 12.64”
C: 100

Gunpowder PS

Portion with low velocity

L: 40’
ID: 12.64”
C: 100

L: 12,400’
ID: 24.94”
C: 68

N
Case Study 2 – Gunpowder & Burlington Force Main

Original Flow Direction

New Flow Direction

Existing 24" Dia. Force Main
Case Study 2 – Gunpowder & Burlington Force Main

Darker flow due to flow reversal in FM resuspending sedimentation
Conclusion / Review

Remember:
- Appropriate FM velocities (~2 – 8 ft/s)
- Reasons why low velocities are undesirable
- Potential complications and consequences
- Contributing factors to low velocities
- Design and O&M solutions

Proper understanding allows:
- Engineers to make better design decisions
- Utility operators to better understand FM O&M issues
- Maximizing FM piping life and reducing life-cycle costs
Questions?

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References


