Vacuum Wastewater Conveyance Systems

PHILIP CRINCOLI—Northeast Regional Manager
Airvac Vacuum Technologies

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Learning Objectives

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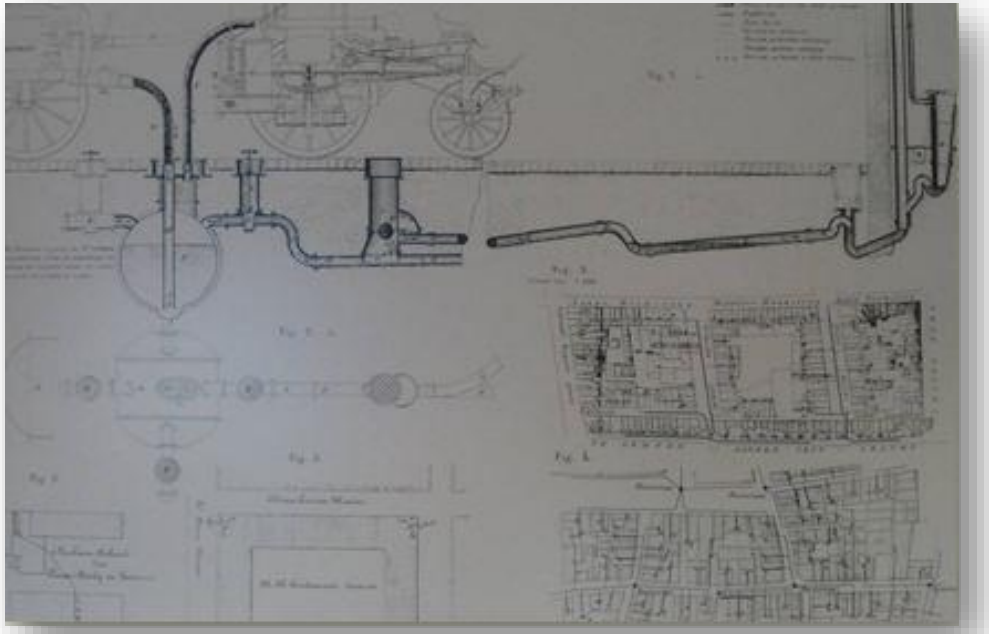
1. Overview of Vacuum Wastewater Technologies
2. Types of Systems-Industrial and Municipal, Indoor and Outdoor
3. Components of a Vacuum Wastewater System
4. How It Works, Why, Costs, Design and Advantages
5. Case Studies and Regional Applications

History of Vacuum

- First used in Europe in 1870. Patented in US in 1888
- Technology introduced to the U.S. by the Electrolux Company
- First US indoor/industrial system was installed in the late 1960's by other manufacturers. Several municipal systems were also installed by others late 60's/early 70's.
- First Airvac system were installed in 1974.



Drawing showing early vacuum system principles
And layouts of actual system
In Prague and Amsterdam – circa 1870

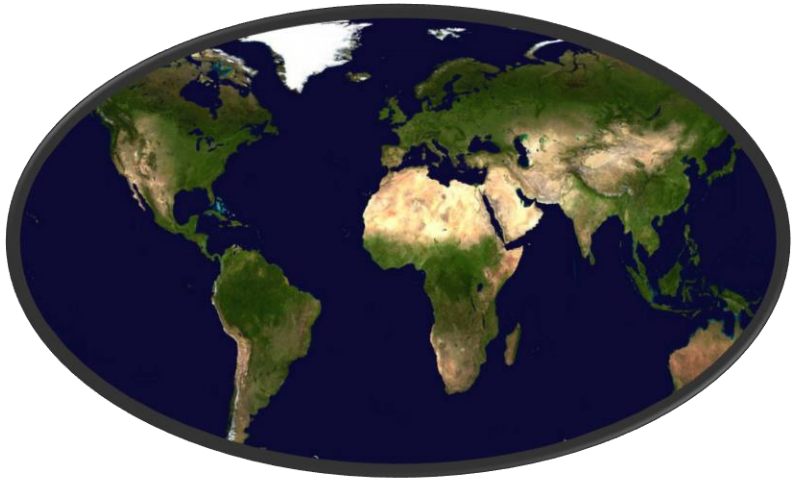
Airvac Systems

400+ Airvac vacuum systems in North America

Including Puerto Rico & Bahamas

700 additional Airvac vacuum systems

in 32 countries around the world



States with Vacuum Systems
As of Dec 31, 2020

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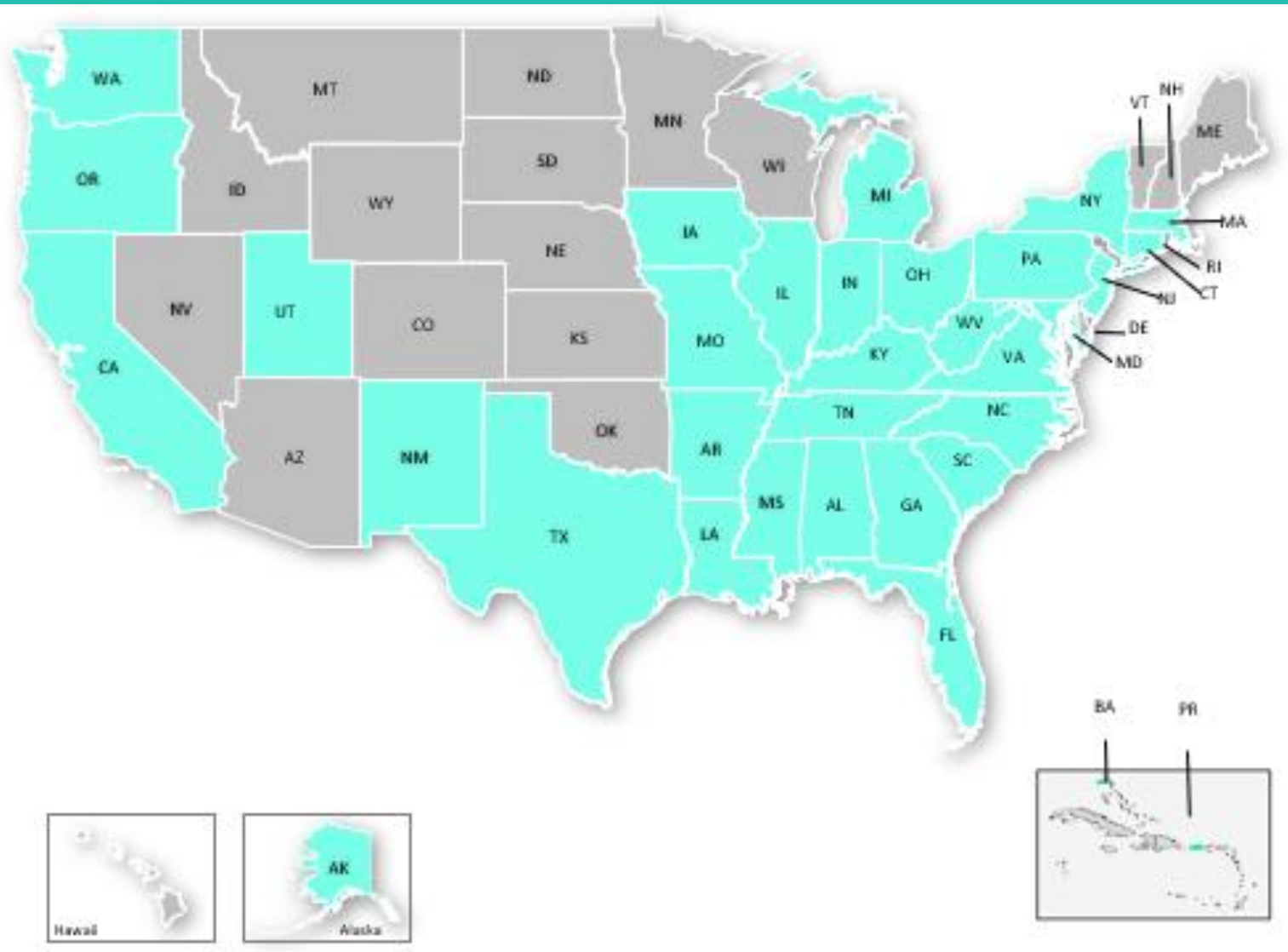
437 vacuum systems in 31 states, Puerto Rico & Bahamas

TYPE	#
Municipal	336
Commercial	18
Industrial	10
Marine	31
By others	42
Total	437



How it Works

Theory of Operation

3 main Components

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How it Works

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Vacuum technology uses a pressure differential between atmospheric pressure and negative pressure (vacuum) as the propelling force to move liquid in a sealed piping system

The vacuum is created by vacuum pumps at a central vacuum station.

Vacuum technology is used a many markets. The 2 primary ones are

- Indoor vacuum systems used in a variety of applications
- Outdoor/buried systems used in the municipal market

How It Works

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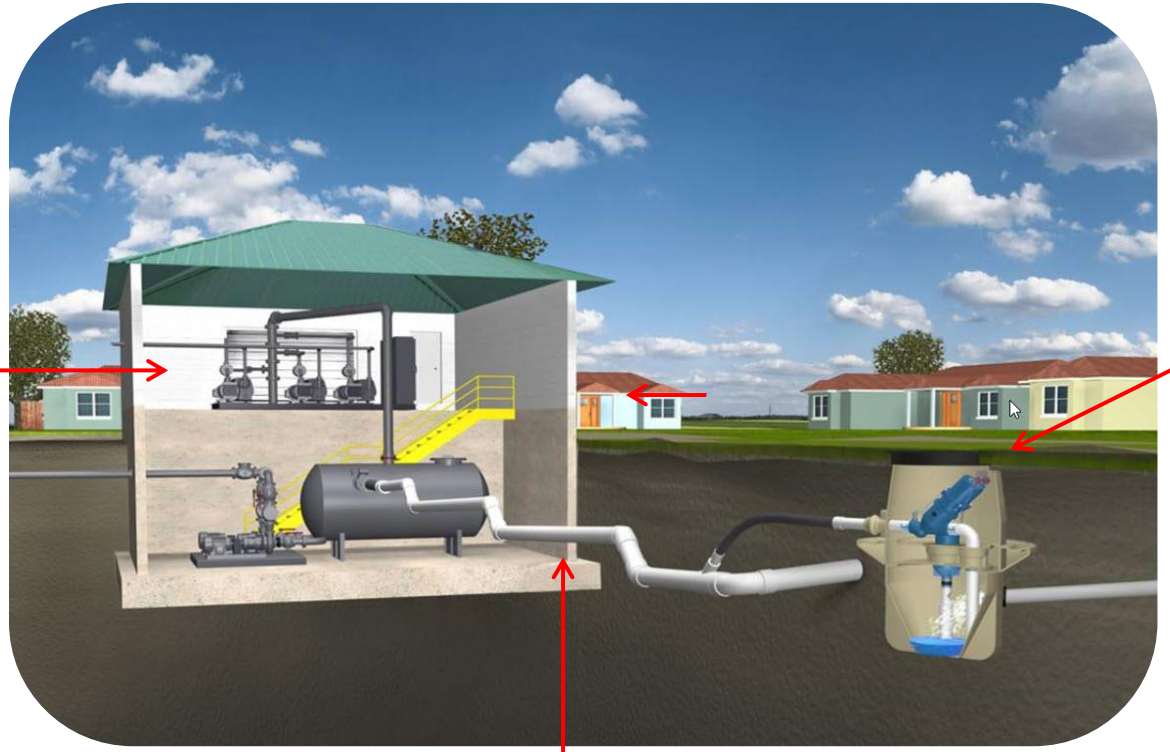
Vacuum pumps create a vacuum on the collection tank then shut off



Valve opens, contents sucked out, followed by atmospheric air.

Differential pressure propels sewage toward vacuum station

Vacuum mains connected to the tank extend the vacuum to each valve pit.

As valves open and admit atmospheric air, vacuum levels in the main drop. This is sensed at the vacuum station & the vacuum pumps turn on run to restore vacuum to an acceptable level.

Airvac Vacuum Sewer Systems
How it Works

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Major Components

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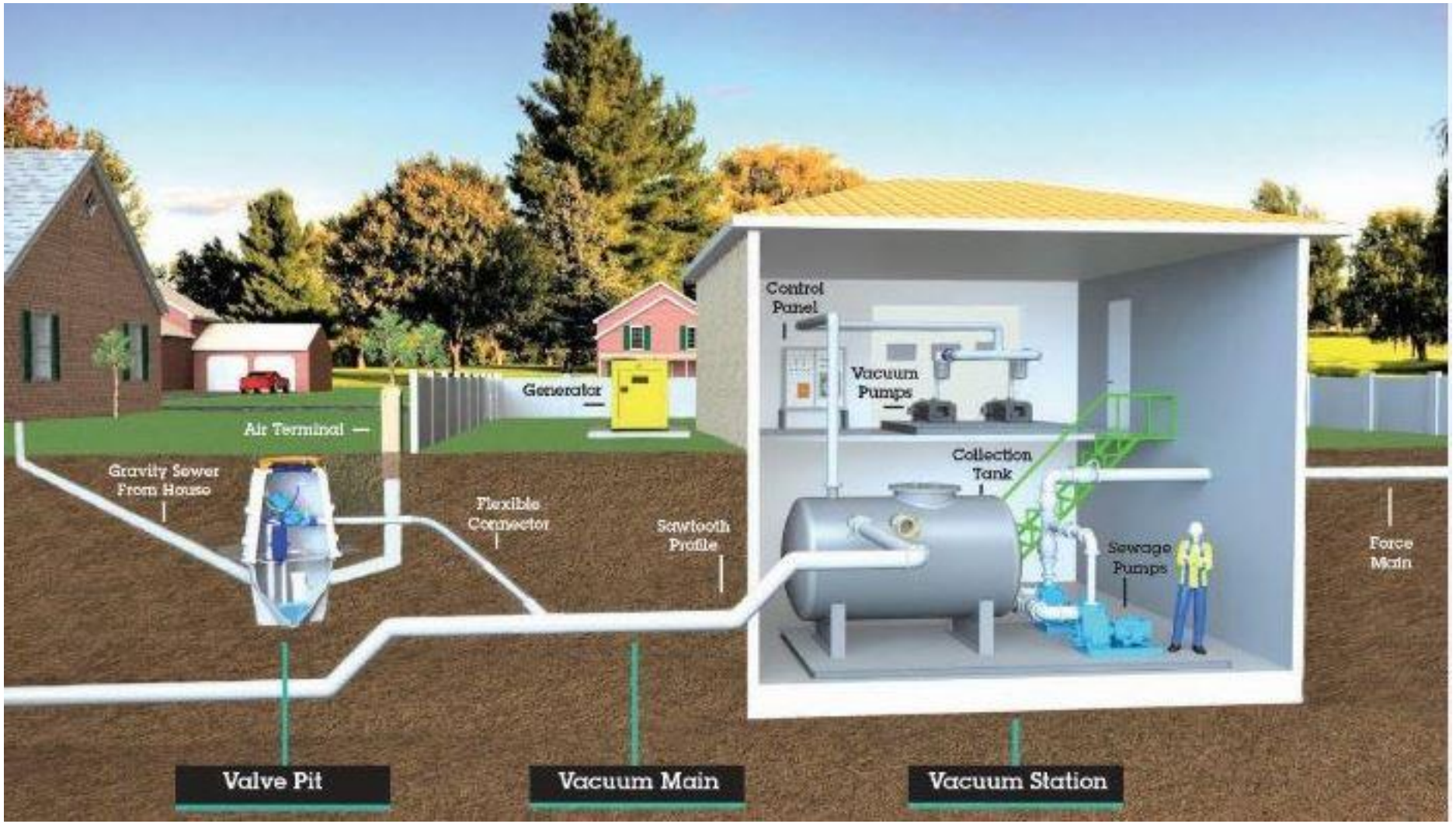


1. VALVE PIT

Material: PE; H20 traffic rated

2-4 houses share a single valve pit

Top & bottom chambers are completely sealed from each other

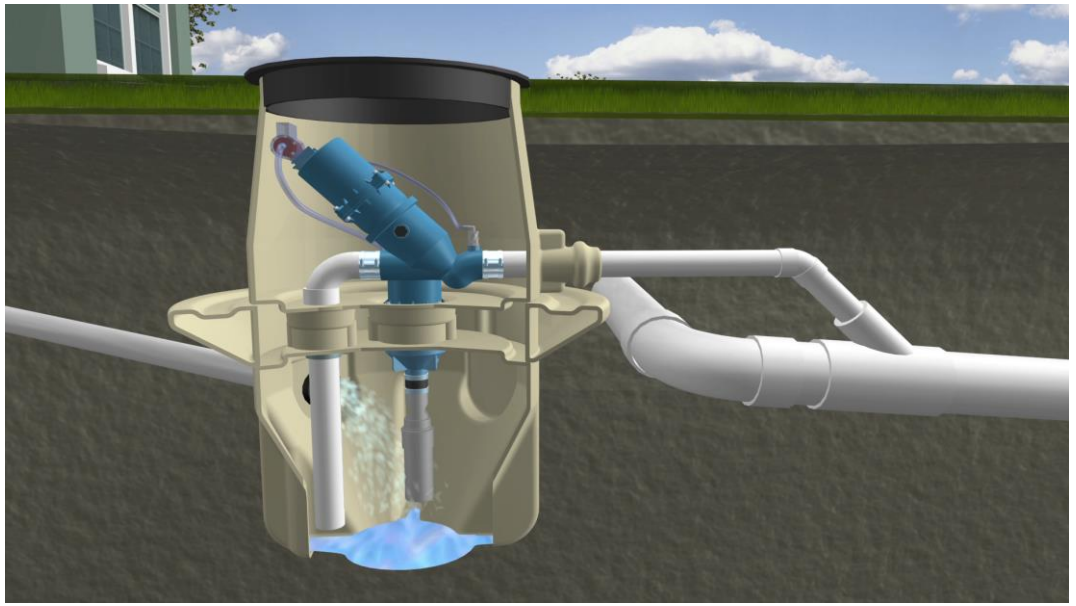
Operator not exposed to raw sewage

Vacuum Technology Systems
Key Points

Airvac

Key Points

- Small diameter piping (4-8 inches)
- Scouring velocity of 15-18 feet per second (i.e. no blockages)
- Average pipe burial depth 3-5 feet
- Narrow trench width from 3-5 feet
- Closed loop system – no external leaks, no exposure to confined spaces & trapped gases



Airvac Vacuum Sewer Systems

Airvac in Action

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Cast Iron Cover

- H-20 traffic rated (not just the cover but the entire valve pit)
- Usually installed in right-of-way
- Concrete collar for traffic situations

House / Pit / Main relationship

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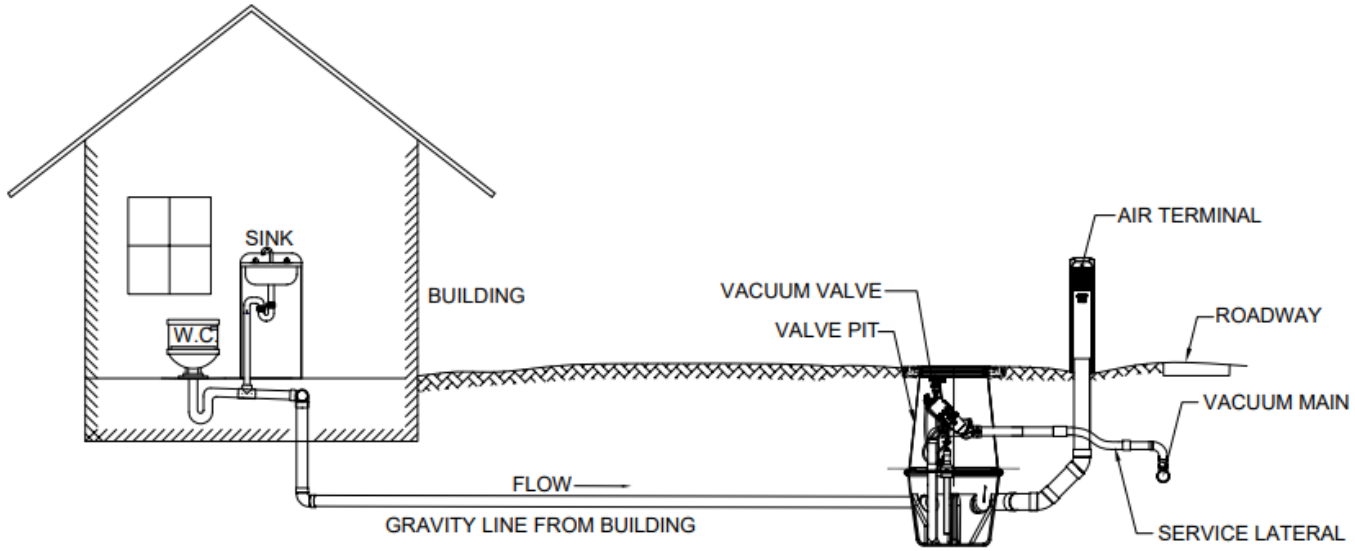
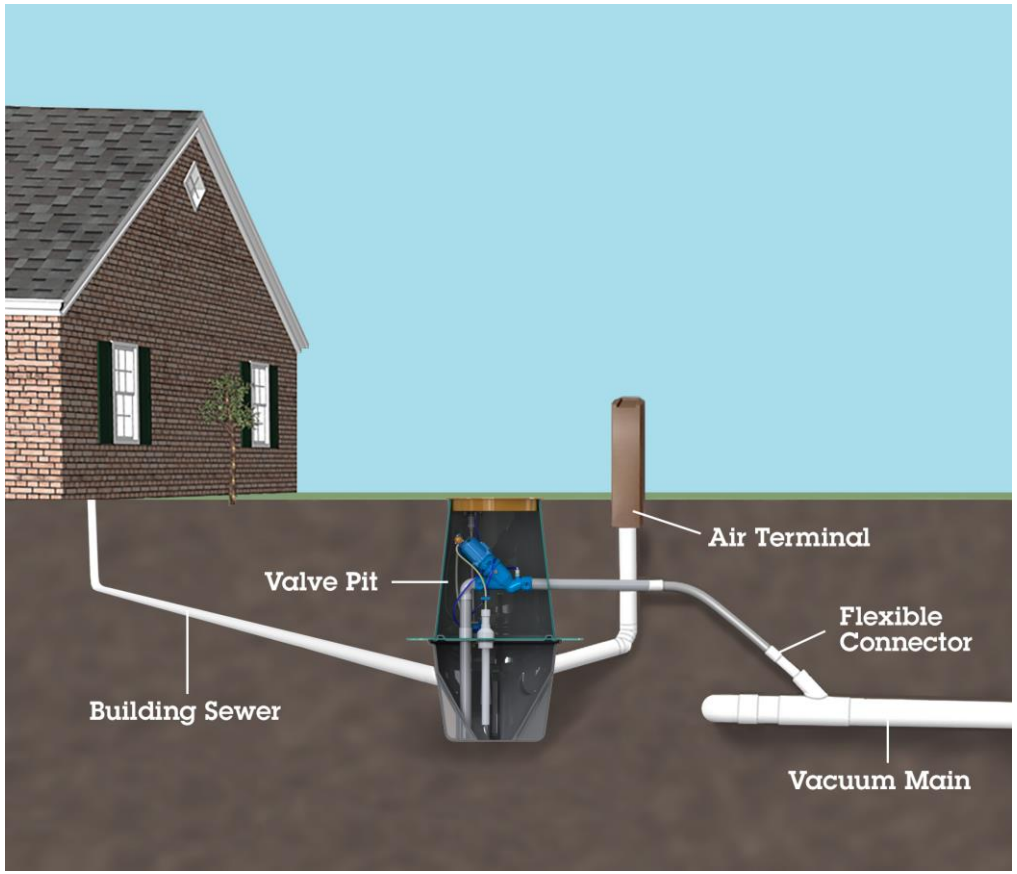


BUILDING SEWER FROM HOUSE



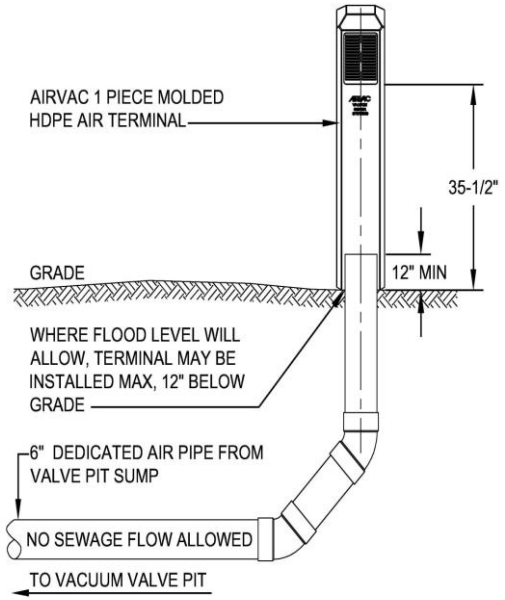
6” Air Terminal (AT)
1 per Valve Pit

Valve Pit

Air Terminal

Air terminal has 2 functions:

1. Source of atmospheric air needed for valve operation
2. Prevents vacuum from pulling traps dry



Air Terminal

Available in simulated stone or utility green

Can add options such as cycle counter or alarm monitoring system

Operator accessible in R-O-W

2 – VACUUM MAINS

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Vacuum

Gravity

Pipe Material

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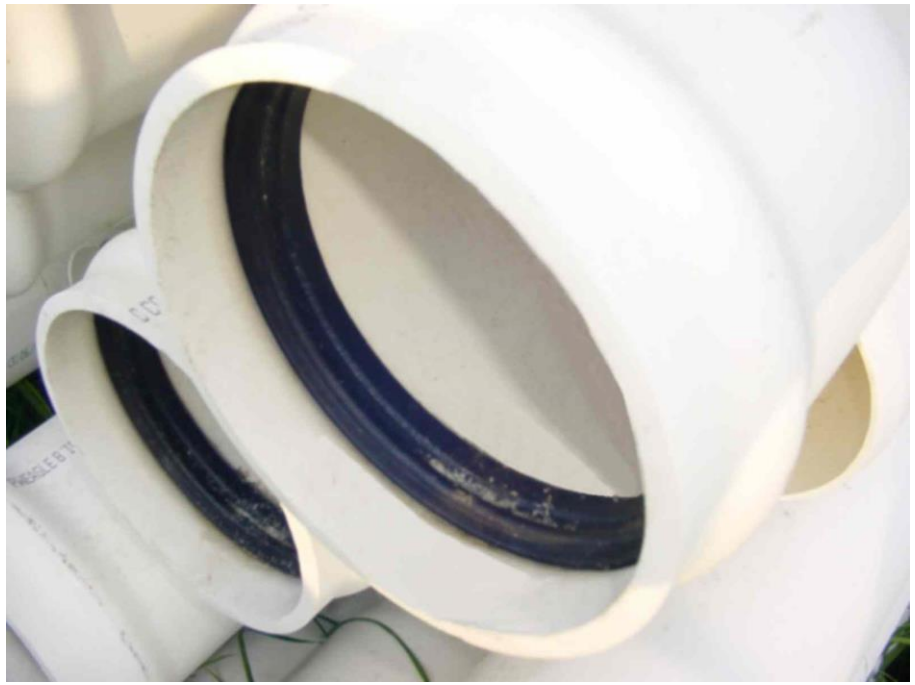
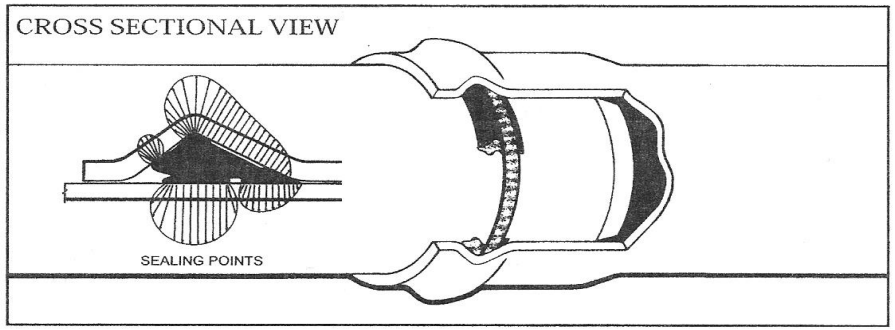
- 4”, 6”, 8”, 10” & 12”
- SDR 21 PVC
- “Rieber” Type Gasket

Rieber Gasket





- Factory installed, double-lipped locked-in gasket
- Reduces installation problems
- Leak proof joints

Sawtooth Profile
“lifts”

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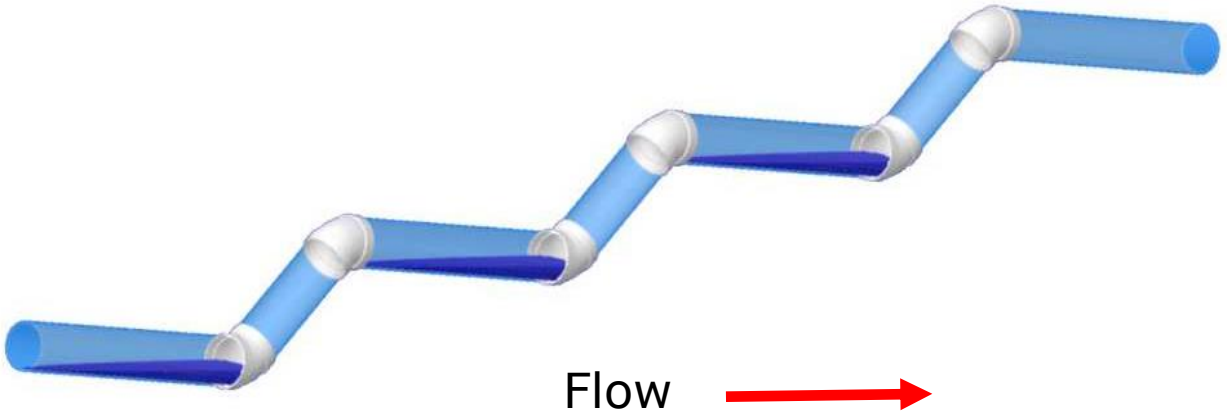
Ensures that the vacuum level created at the vacuum station is transferred throughout the entire piping network to the vacuum main extremity.

This is done by keeping an open passageway at the top of the pipe (1/3 sewage and 2/3 air)



Pit to main connection
Flex Connector

This is a fixed point

Flex connector provides a degree of flexibility to allow connection while avoiding overuse of fittings

This also is a fixed point most likely at a different elevation than the valve pit opening

3 – VACUUM STATION

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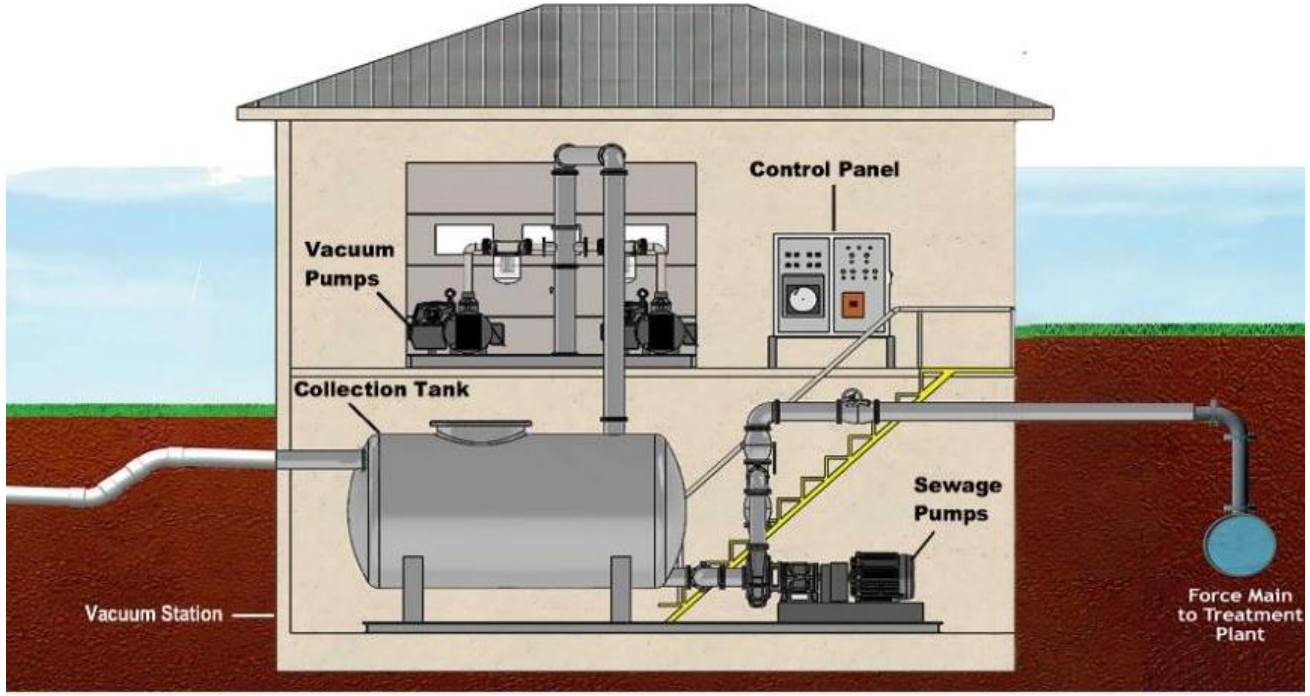
Equipment typically housed in a 2-level building

Vacuum Pumps & Control Panel on top floor



Sewage Pumps & Collection tank in basement

PacVac
For small to medium sized projects (75-550 conn)

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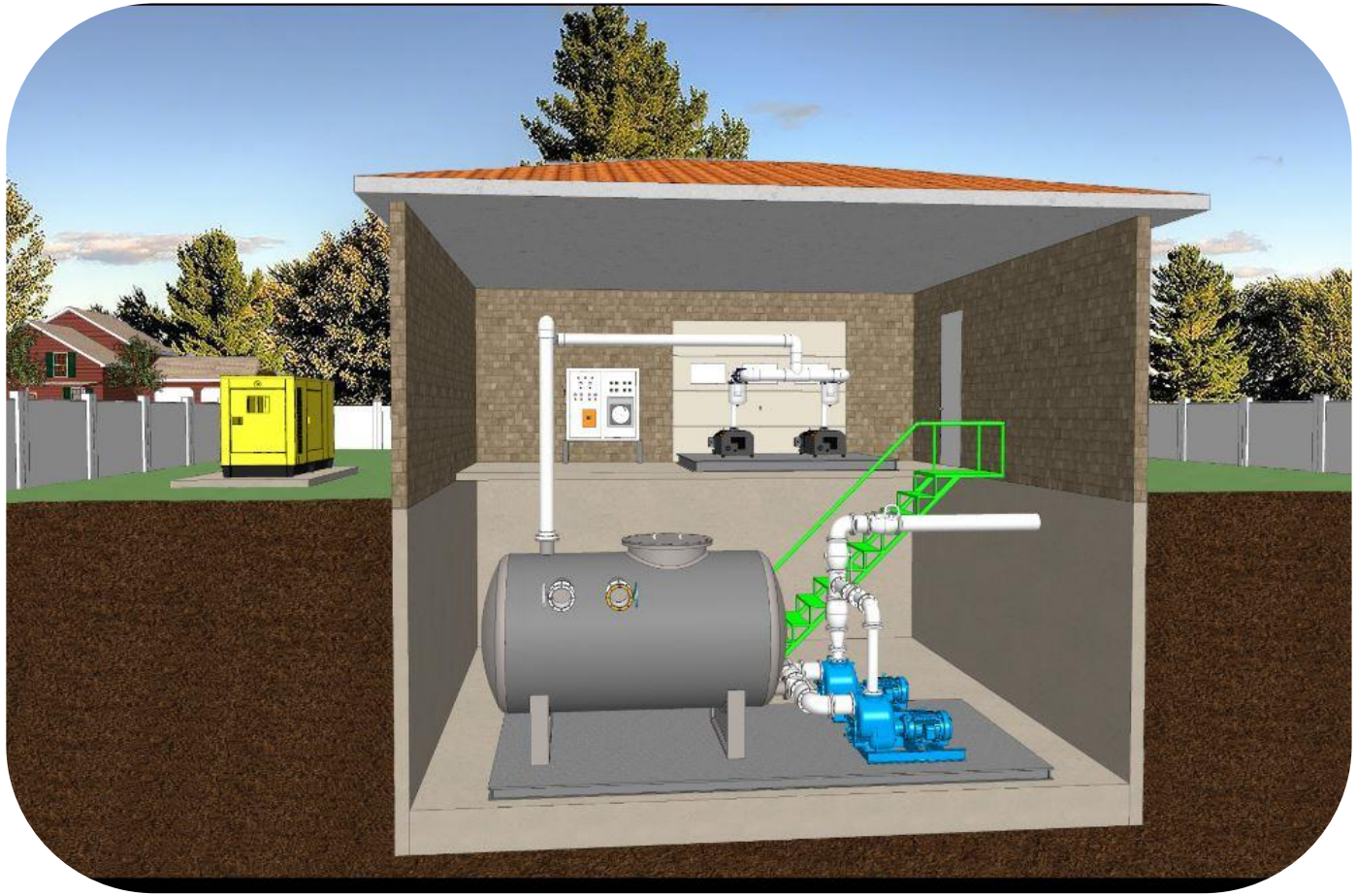

By AIRVAC

- Prefabricated building (top part)
- Vacuum pumps
- Sewage Pumps
- Control Panel
- Collection tank
- Generator *(Generator could be supplied by others as well)*

By Contractor

- Basement vault
- Place skid & building on vault
- related site work

EFI Prefab Building
For PacVac

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Example of an EFI prefabricated building

- Single enclosure dimensions up to 16’ x 62’
- Placement on piers, slab or foundation wall
- Available with or without floors
- Code constructed
- Electrical and mechanical systems outfitted
- Various exterior finishes
- Various roof shapes and materials

Prefabricated Vacuum Station

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PacVac – Longwood, FL

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PacVac -Broadcreek PSD, SC

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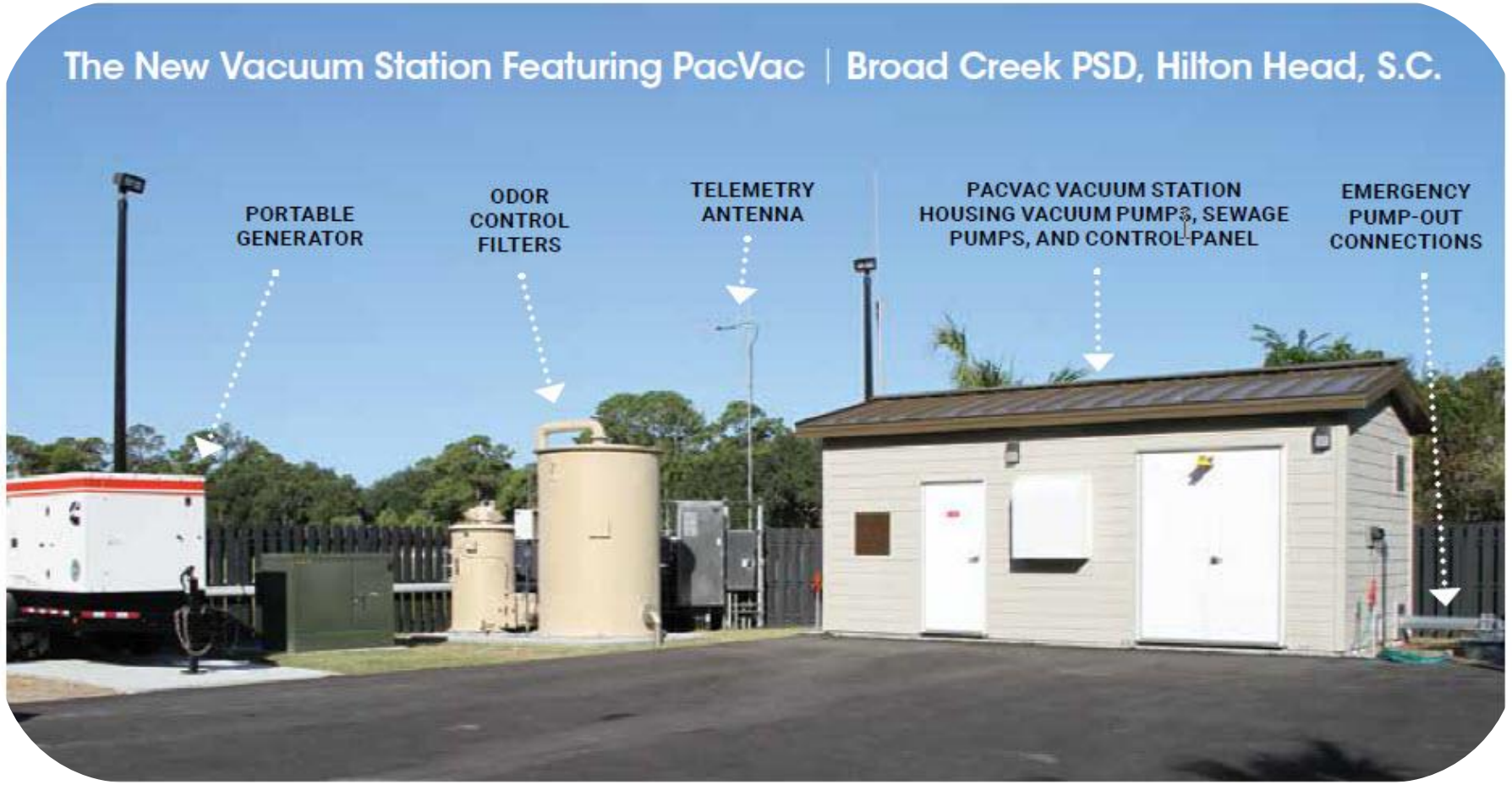
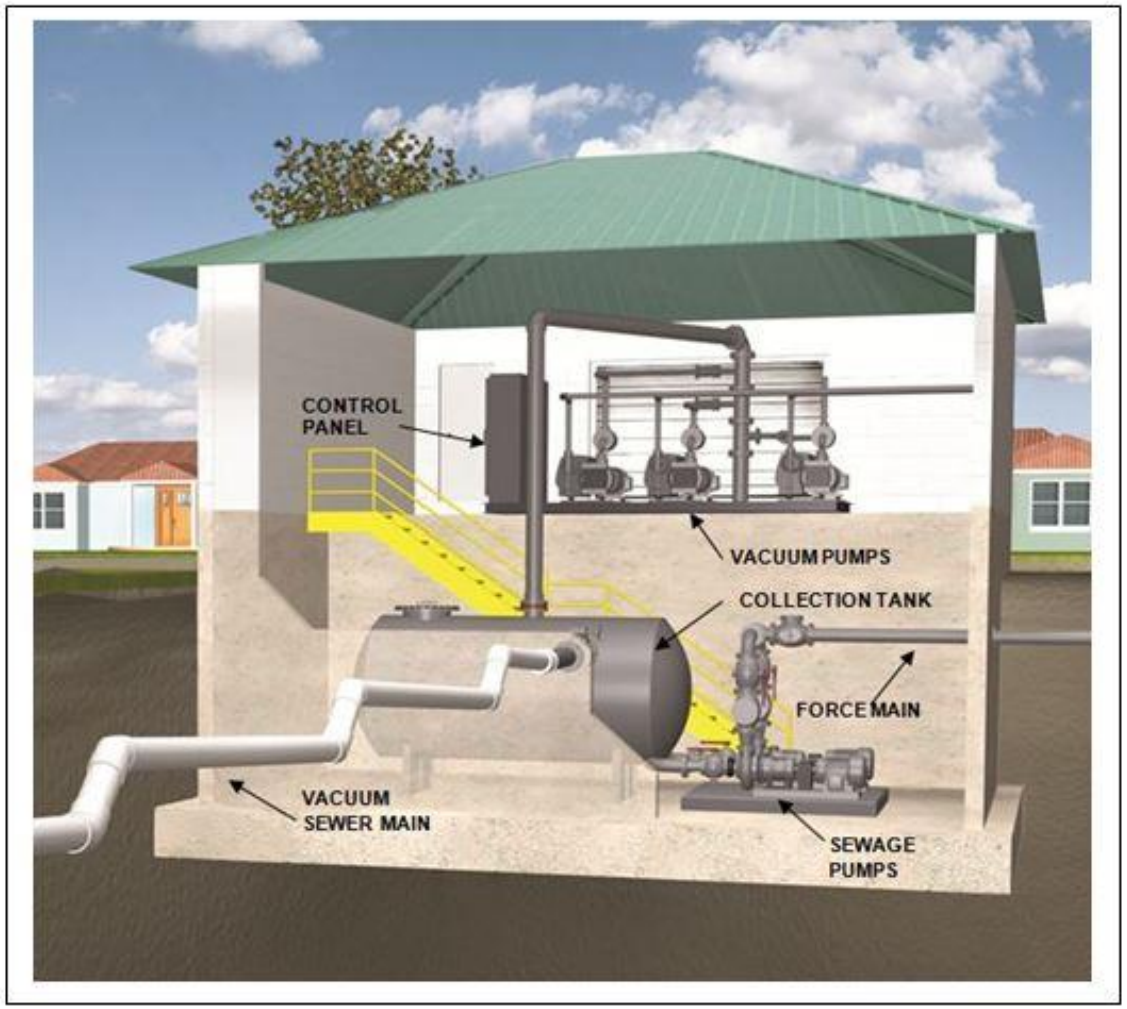


Featured in March 2020 Water & Waste Digest magazine
Cover Story

Custom Over/under configuration
for larger projects (> 550 conn)



By AIRVAC

- Vacuum pumps
- Sewage Pumps
- Control Panel
- Collection tank

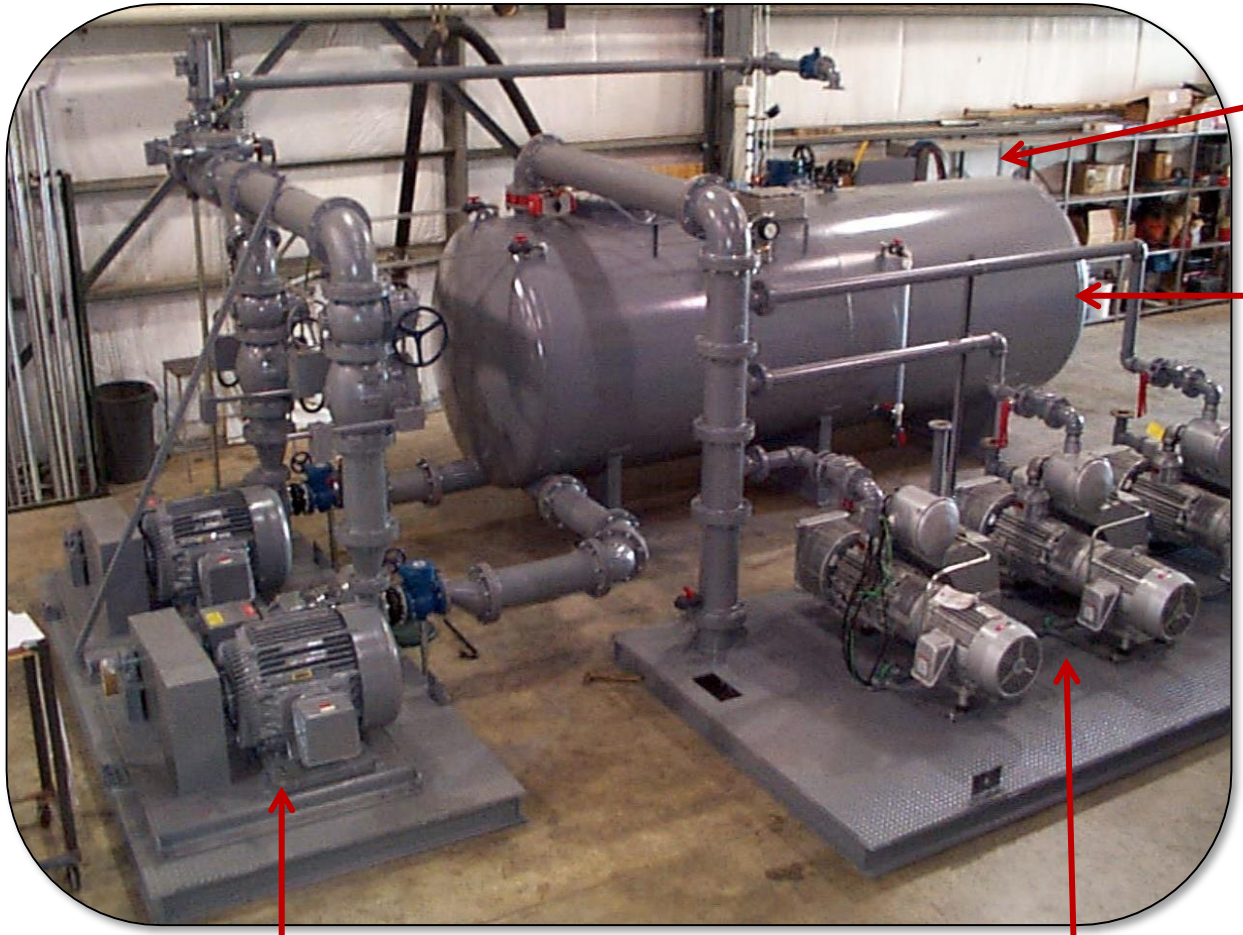
(equipment supplied on skids)

By Contractor

- Construct building
- Place skid(s) in building
- Generator
- Related site work

Vacuum Station Skid
At Airvac factory

Airvac



CONTROL PANEL
(on back side)

COLLECTION TANK

SEWAGE PUMPS

VACUUM PUMPS

Emergency Generator

A standby generator provides uninterrupted service during power outages.

May be either a fixed, permanent generator or a portable generator

Odor control
Bio-filter

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Exhaust from vacuum pumps is distributed evenly throughout bio-filter

In some cases, exhaust is just piped directly to atmosphere

Next generation technology

&

case studies

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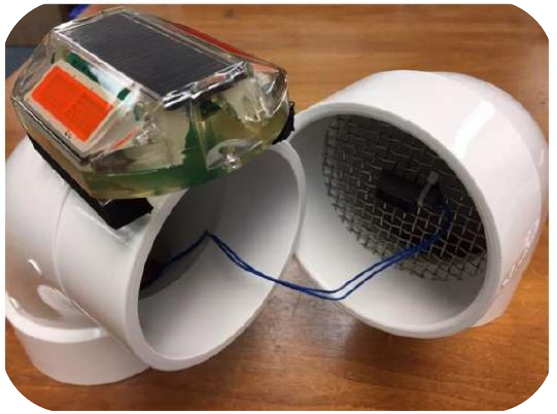
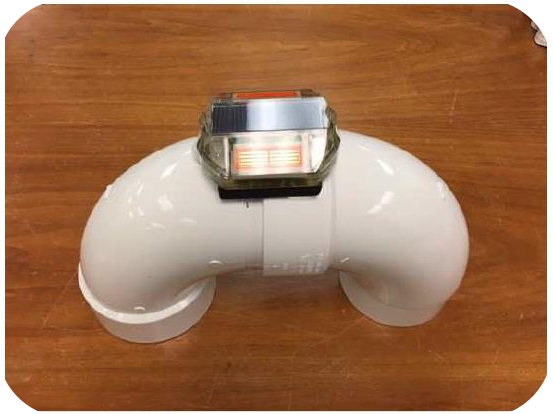
Solar Monitoring Light

- Solar Monitoring Light as the first level of monitoring available
- Identifies a hung open valve by a flashing light
- Low cost
- Easy to install
- Old systems can be updated
- Mounted on 4” air intake or on Airvac Dedicated Air Terminal





Airvac Monitoring System

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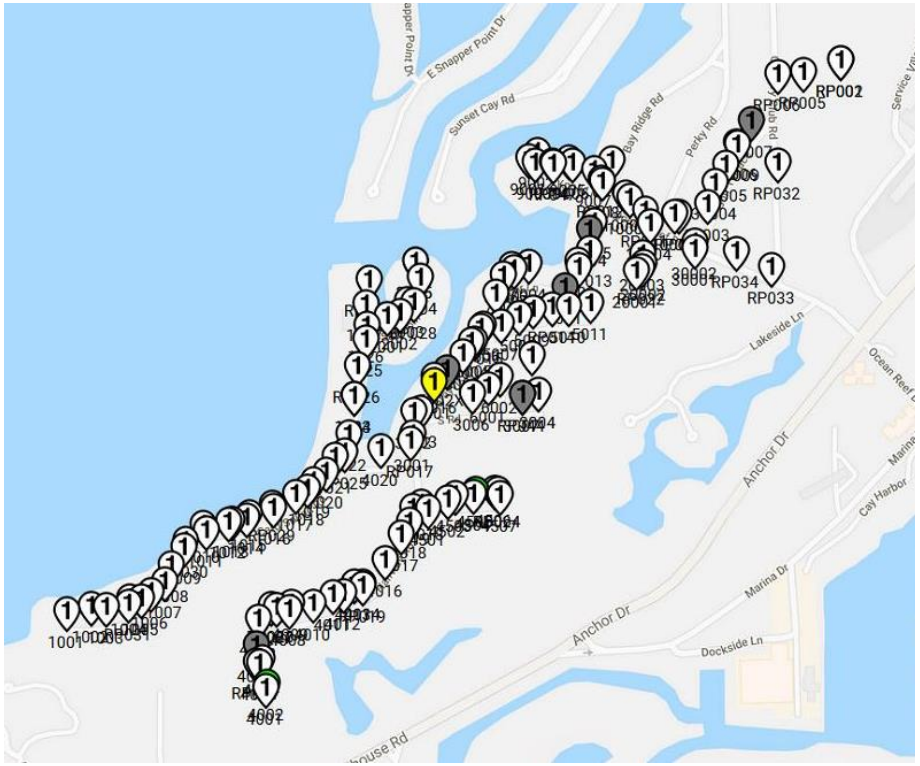
- Monitor each valve pit with:
  - Valve cycle
  - Valve Open Time
  - Hung Open Valve
  - Sump Level
- Monitor end of line vacuum level
- Monitor vacuum pumps runtime
- Monitor sewage pumps run time
- Customized alarms
- Ability to track trends
- Ability to pin-point problems



Vacuum Technology Systems
Internet of Things & Artificial Intelligence

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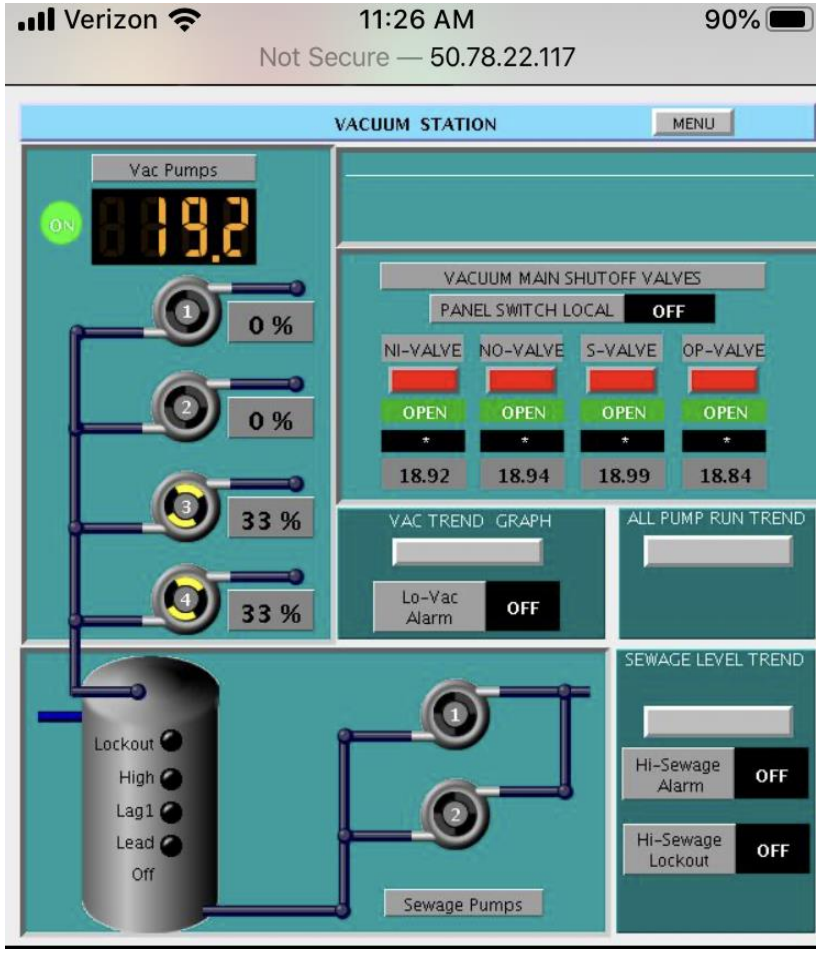

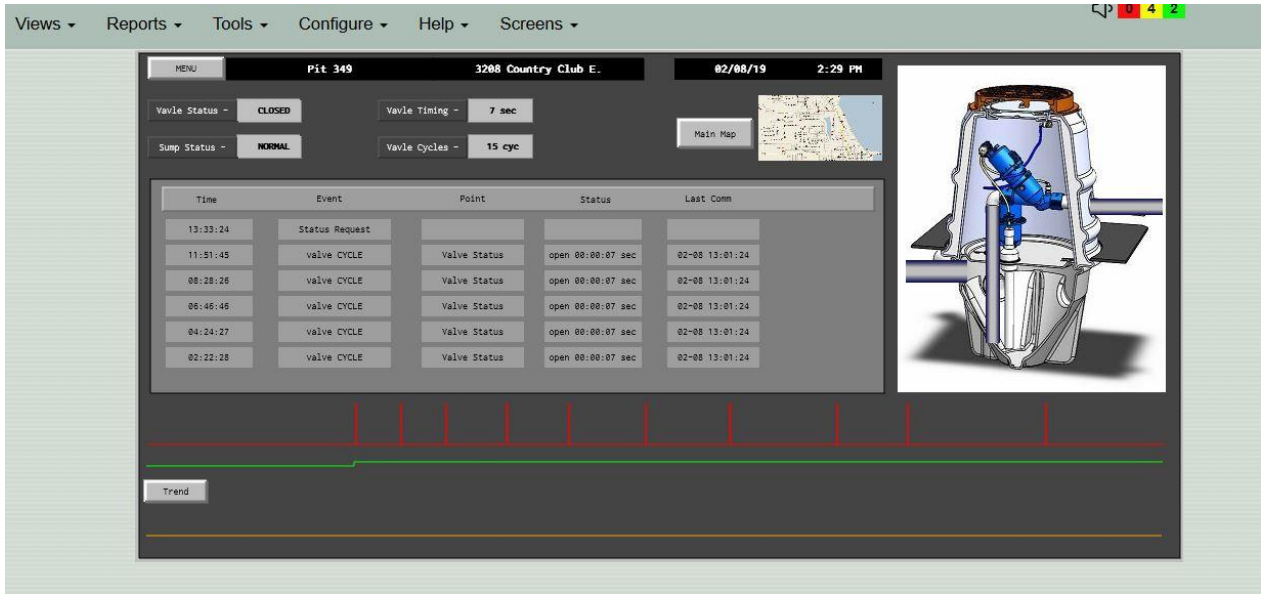

Vacuum Technology Systems
Internet of Things & Artificial Intelligence

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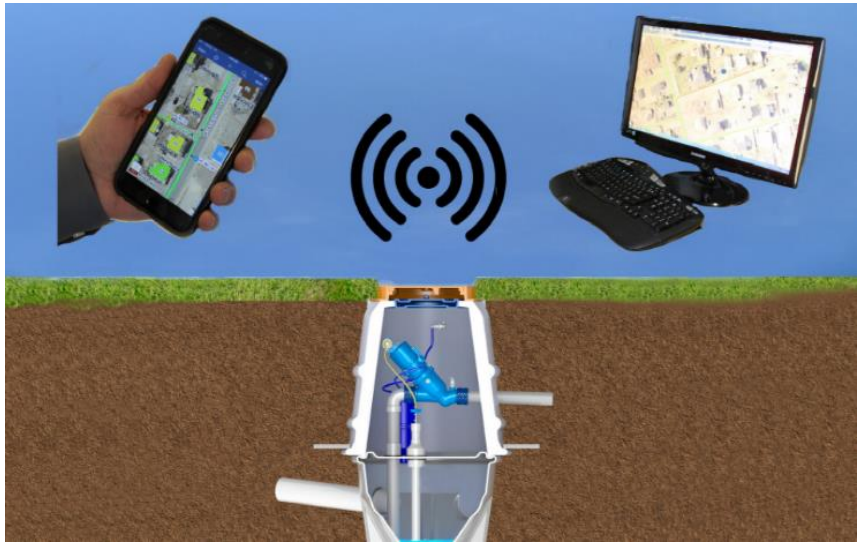
Target: (PDS) Further develop our IoT & AI portfolio

- ***SMART*** (Strategic Monitoring for Advanced Remote Transfer)

  - Use AI to recognize imbalances before they occur & react accordingly without operator interface
  - Proactively purges the system prior to high flow periods
  - AI to decrease vacuum pump noise, heat & power cost, while improving system performance
  - (2.0) Automatically corrects low vacuum alarms after hours/weekend



Vacuum Station

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Alloway, NJ

# Vacuum Stations	# connections served	Year system went into service
1	200	2009

Alloway Township NJ
Vacuum Sewer System

- 1 Vacuum Station replaced 3 pump stations
- 2500 population
- Completed in 2009
- SW NJ near junction of Delaware River and Delaware Bay
- Very high-water table and tidal
- Leaking septic tanks
- Survived and continued to run during major hurricane
- Sister town of Quinton experienced gravity system failure and sewage discharges during same hurricane event

Alloway Twp NJ Vacuum Station

Alloway, NJ Vacuum Station

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https://youtu.be/-jkN-gzzrIs

- Project saved over 25% over standard gravity
- Excavation was 4-6 feet vs 22-24 feet in depth
- Excavation was 4-6 feet wide vs entire street
- System was first in kind in State of NJ in 2009
- Design Firm working on new 2020 project now
- No sewage discharge during hurricane after area floods
- System remained fully operational during hurricane
- System is designed to work under water & power outage
- Limited I & I as system is closed under pressure
- Saved $180 annually in sewer bills for residents

Cape May County, Villas, NJ
Lower Township, NJ 2021

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# Vacuum Stations	# connections served	Year system went into service
1	1100+	2022

System in construction in 2021

Cape May County, Villas, NJ
Lower Township, NJ 2021

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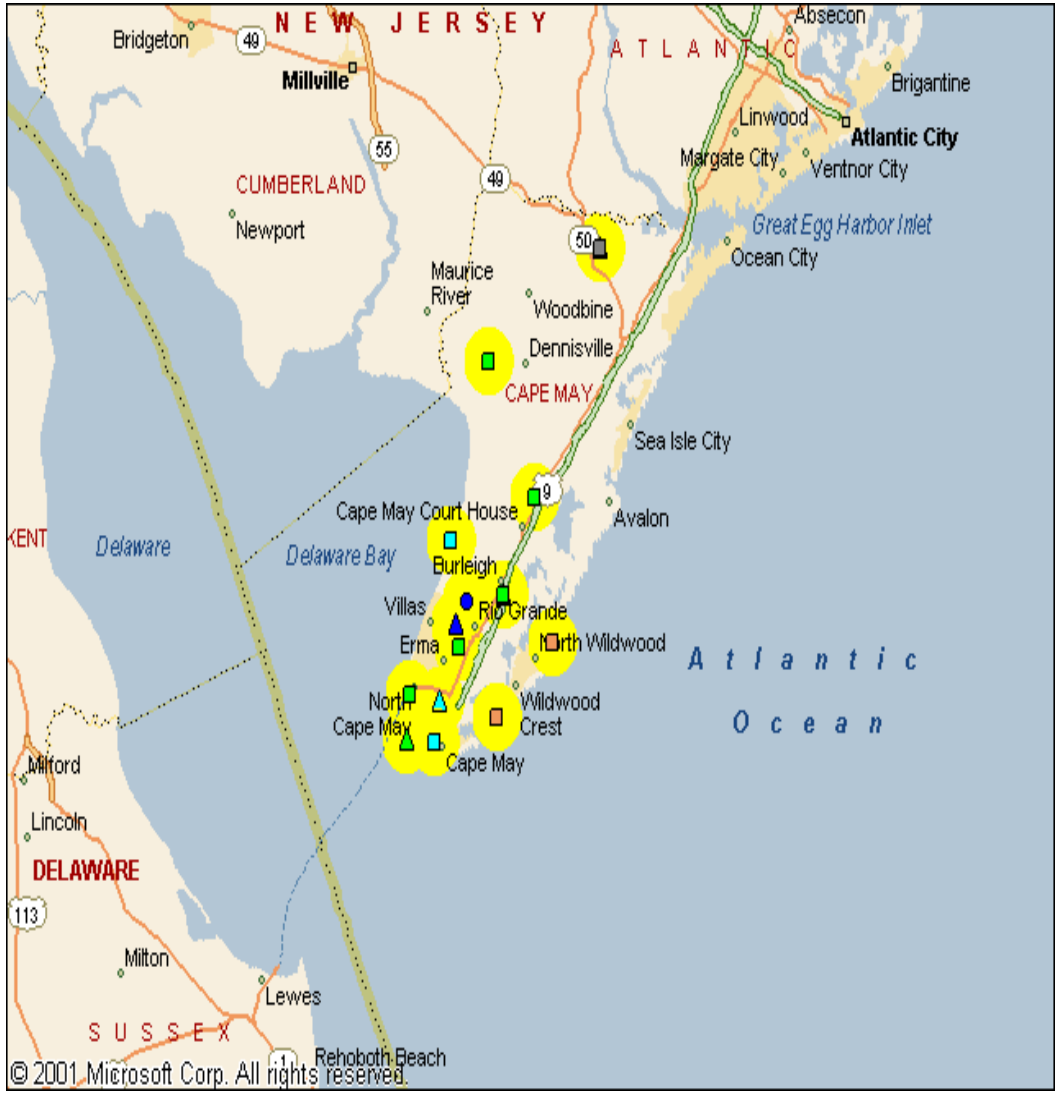
- Designed by Fralinger Engineering (did Alloway in 2009)
- Second vacuum sewer system in NJ. Third system overall.
- 2 Vacuum Stations are EFI buildings
- Construction July 2021 through 2023 with 2 phases
- Total estimated Value $4.5M +
- Area near CM Airport off Bayshore Road (4 miles from GSP)
- Very high-water table and tidal
- Leaking septic tanks
- 550 valve pits
- 1100 connections
- Smart Monitor System and Solar Light Alarm Systems
- Possible additions to system under consideration for campground including indoor vacuum toilets and fixtures and additional 1100 connections under consideration to current system
- Client Forum September 27-28 in planning stages



Vacuum Station

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Plum Island (Newburyport), MA

# Vacuum Stations	# connections served	Year system went into service
1	1,050	2006

Vacuum Station

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Provincetown, MA

# Vacuum Stations	# connections served	Year system went into service
1	2,250	2003

Ocean Shores, Washington

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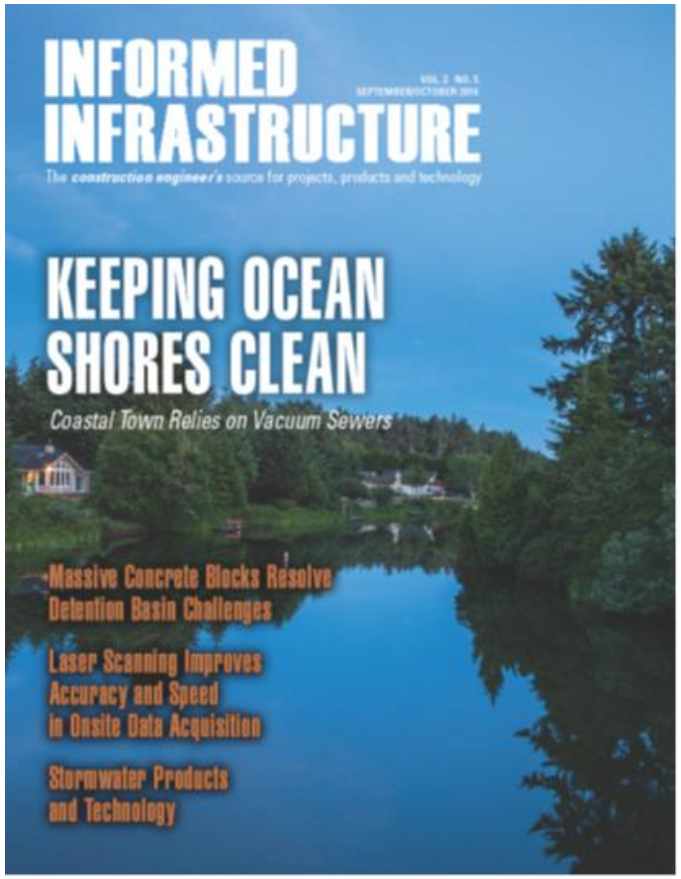

Community of Rockridge
Indian River County, FL

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Storm-Proof Sewers

Florida community learns lessons during hurricanes of 2004.

By Donald Eckler, P.E.

The citizens of Central Florida will never forget 2004. Within a six-week period three major hurricanes hit the peninsula. The storms left a trail of wrecked homes, flooded neighborhoods, and tens of thousands of displaced people.

First came Hurricane Charley. It made landfall near Punta Gorda in mid-August and did major damage to that area and then continued to dump heavy rain across the middle of the state. On September 4, Hurricane Francis came ashore on the east coast near Fort Pierce, and then moved across the state before heading northward through the panhandle. Less than three weeks later Hurricane Jeanne made landfall at almost the same location before moving up the Atlantic coast and into South Georgia.

Needless to say, Florida was devastated, especially its utilities as some areas experienced a loss of power. Electric utilities were lost for weeks. Roads were flooded making access and repair extremely difficult. Communications were also affected due to the loss of telephone relay towers and downed power lines.

The Indian River County community of Rockridge was particularly hard hit. Located just 20 miles north of Fort Pierce, the city lost electrical service for two extended periods of time, ten days after Hurricane Francis and 14 days after Jeanne. Without electricity, the community's low-pressure grinder pump sewer system was shut down. Sewage backed up into homes and contaminated the area's groundwater. Entire neighborhoods became giant bacteria-producing Petri dishes.

"It was bad," said Phil Carpenter, president of the Rockridge Homeowners Association. "When we came back, everything had to be destroyed, the sheetrock, furniture, carpets, all of it. We had to spray everything with bleach and chemicals to kill the bacteria. Rockridge is primarily a retirement community and many of the homeowners are in their eighties, so it was an especially difficult situation for them."

Vacuum sewer service lateral installation is simplified because lines are shallow and can easily be diverted over or under buried obstructions.

When it came time to rebuild Rockridge, the community turned to the federal and state governments for funding. Various agencies looked at Rockridge's low-pressure grinder pump sewers and declared the system condemned. They saw no need to repair a system so susceptible to power loss and prone to environmental nightmares such as the one that occurred in 2004.

After much study and deliberation, community leaders and utility department engineers decided to install a new AIRVAC (www.airvac.com) vacuum sewer system. The new system, which went online in mid-2008, solved a host of problems. Furthermore, the project was completed under budget and several months ahead of schedule.

"The residents of Rockridge got a very good deal and they are happy with the results," said Larry Brown, environmental engineer for Indian River County Utilities, which manages the sewers for Rockridge. "I was initially reluctant to work with a vacuum sewer

Advantages & Applicability

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Cost Savings

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Vacuum

Shallow, narrow trenches = less excavation

Dewatering minimized

Smaller equipment

Smaller diameter pipes

1 vacuum station can replace 6 or 7 lift stations

Gravity

Reduced Impacts From Construction

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- Less surface disruption
- Less restoration
- Vertical & horizontal routing flexibility

Protects Ecosystem

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Completely sealed system
(no spillage = no permit violations)

Self scouring
(unlike gravity where period cleaning is required)

Infiltration & Inflow eliminated

A leak in a gravity sewer can go undetected/uncorrected and allowed to continue to pollute for a long period of time

A leak in a vacuum system is automatically detected and MUST be corrected for the system to continue to function economically

Operator Friendly

Airvac

Completely sealed system

No operator contact with raw sewage

Environmental Friendly

Aesthetics

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Vacuum stations are typically designed to take on the character of the neighborhood

The vacuum station on the left is in the same neighborhood as the house on the right

Advantages in hurricane prone areas

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WWTP not inundated with I&I	Sealed system prevents I&I so plant is not overwhelmed
Less preparation required	In coastal areas 1 vacuum station typically replaces 7 lift stations; less storm prep required of staff
Uninterrupted service	All vacuum stations have emergency generators which provide uninterrupted service to the customer
Safer working conditions	Fixed generators automatically start…no need to expose maintenance staff to severe weather
As last resort the system can be shut down	If water levels rise to the point where the Air Terminals are flooded, the system can be powered off to prevent damage to system components. After the threat is over, service to customers can quickly be restored

Where does it apply?

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Where does it apply?

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- New developments
- Existing communities
- Flat / rolling terrain
- Rock / high groundwater
- Sandy / unstable soil
- Sensitive eco-system

Subsurface conditions

If any (or better yet, a combination) of the following conditions are present, the narrow and shallow trenches associated with vacuum give it a cost advantage over gravity

- High groundwater table
- Sandy and unstable soils
- Rock
- Buried obstacles

Ideal candidate

- An existing community on septic tanks
- 100 to 2000 connections
- Primarily residential
- Flat topography or not much elevation to overcome
- One or more subsurface difficulties to overcome

Bonus: If the area also is environmentally sensitive.

The more difficult the project, the more likely vacuum is cost-effective.

Not particularly good candidates

- Projects with not many connections (<30)
- Projects with too much elevation to overcome
- A project with all commercial/industrial users, especially if in a highly dense area
- Lake communities where the houses are at an elevation well below (10 ft. or more) the road.
- Areas with repetitive up and down topography
- New developments that could easily be served by gravity with only 1 or maybe even no lift stations

Vacuum vs Low Pressure

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Comparison
Vacuum vs Grinder Pump

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ITEM	VACUUM	LOW PRESSURE (GP)
# houses served by 1 unit	Typically 2; up to 4	1
Power supply	1 source @ vacuum station	Power required at each house
Standby generator	At vacuum station	None. Not practical at each GP
Rebuild cost	Valve & controller rebuild < $100	GP rebuild > $1,200
Rebuild frequency	Valve: 15 yrs Controller: 10 yrs	GP: 5 to 7 years
Emergency maintenance	Typically only requires 1 person	Typically requires 2 persons due to weight of unit & dealing w/electricity
Leaks	Sewage cannot escape; air comes in & is detected at the VS	Under pressure goes into ground, can go undetected

Lower O&M, more operator friendly, environmentally safer

Vacuum vs Low Pressure
Capital Cost - Overall

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	< 50 connections	50-200 connections	> 200 connections
Low Pressure	✓	✓	
Tossup		✓	
Vacuum			✓

Systems serving 50 - 200 connections generally favor Low pressure.

Unlike gravity where difficult conditions tilt toward vacuum, this is not the case with low pressure as they have the same advantages as vacuum in difficult conditions.

Wrap-up

Reference Material

Review

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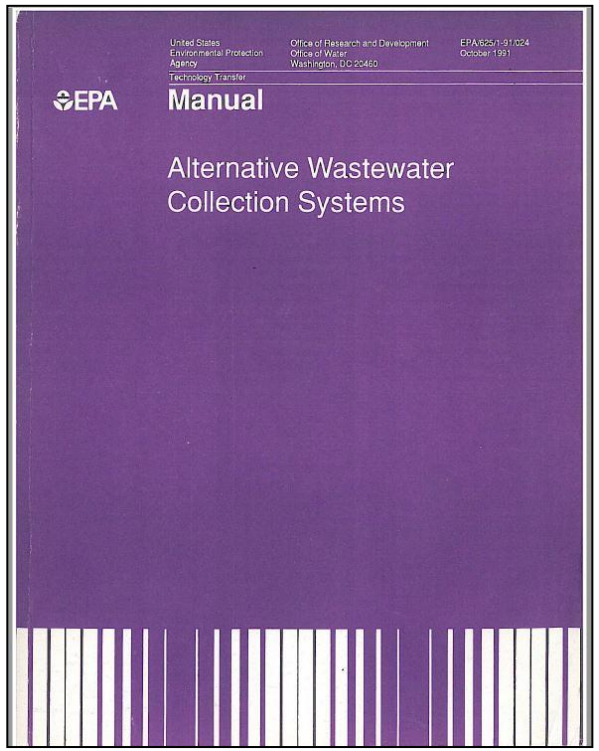
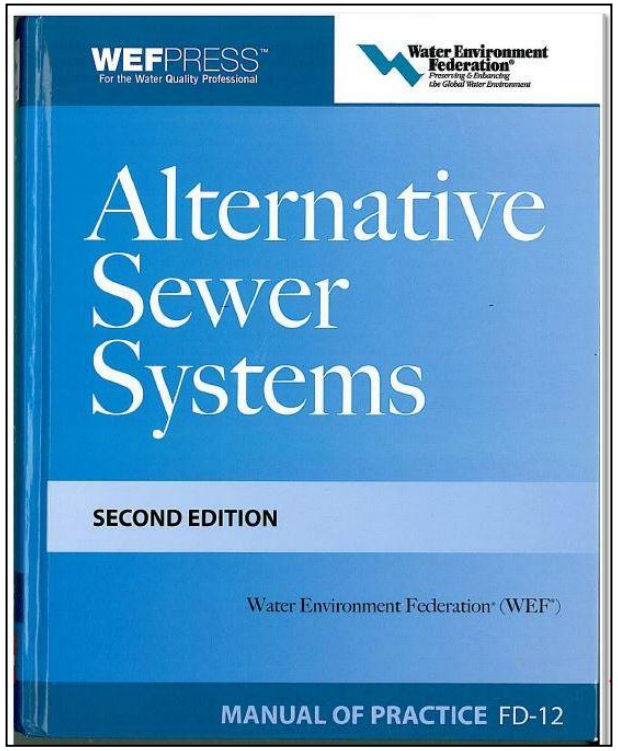
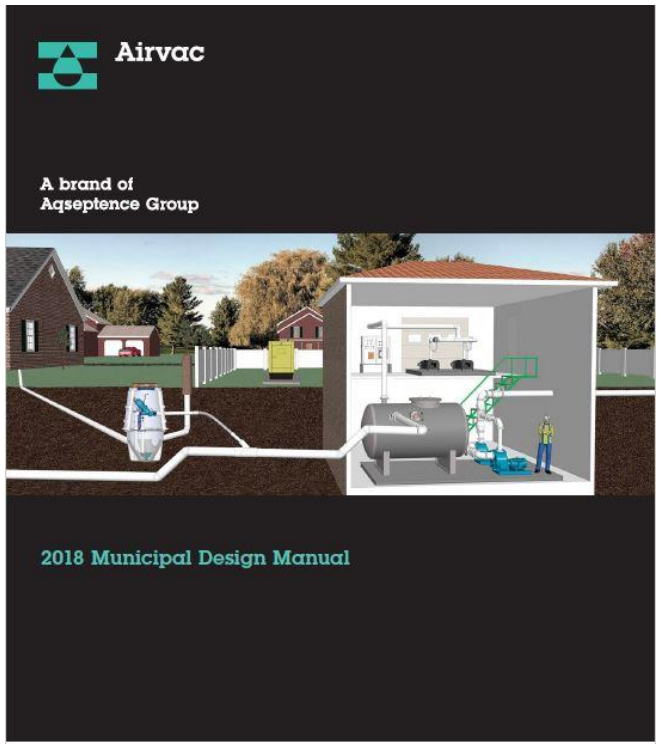
Reference material
Vacuum sewers

There are 3 main reference documents on vacuum sewers



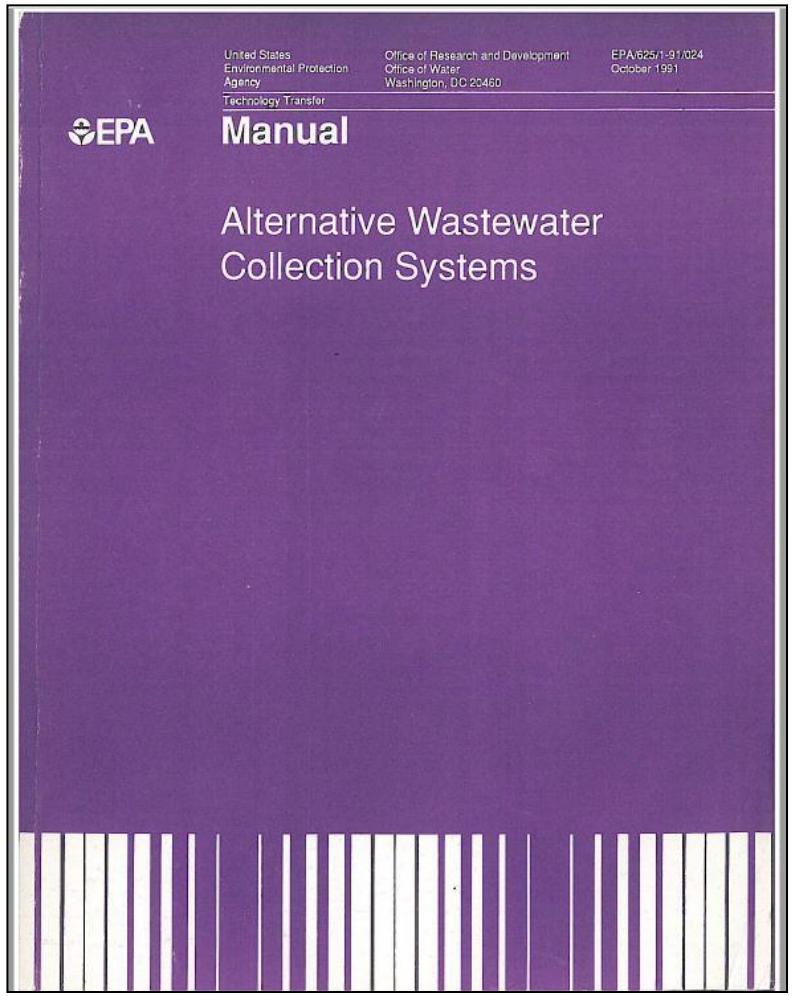




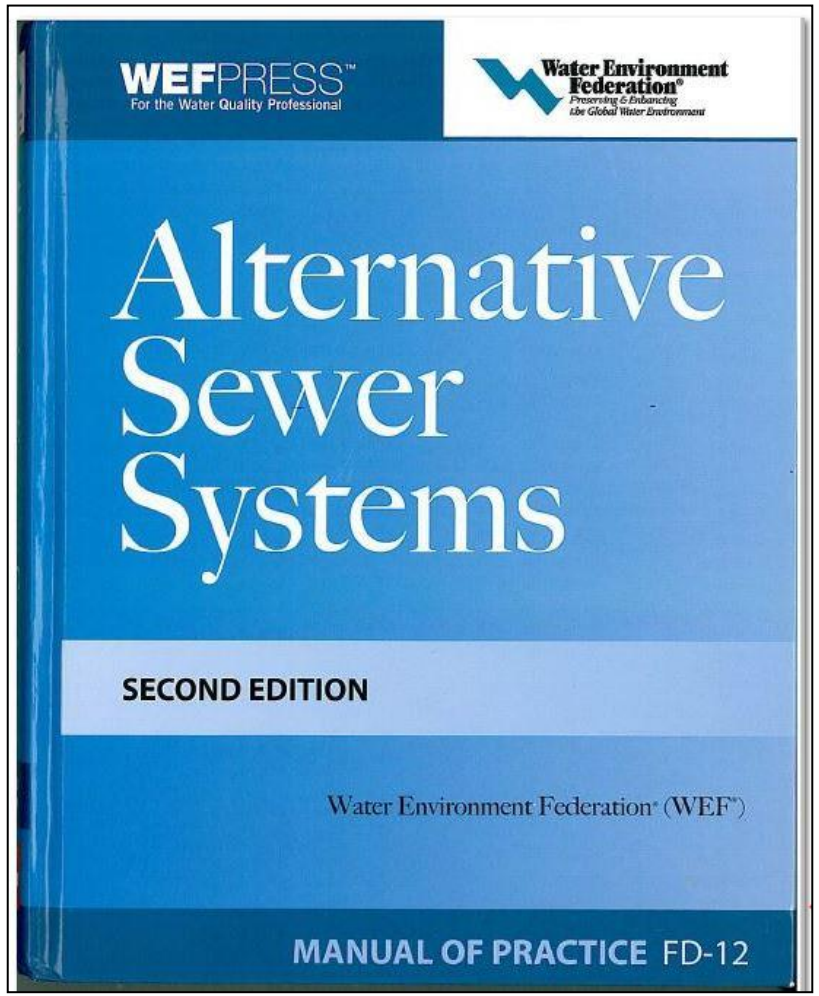
EPA Manual
EPA/625/1-91/024

Airvac

- Includes chapters on Low-pressure sewers, vacuum sewers and small-diameter gravity sewers
- This was published in 1991
- At the time and until the WEF Manual was published in 2008, was considered to be the industry standard for alternative sewer systems in the US.
- Rich Naret, P.E, (Airvac) authored the vacuum chapter

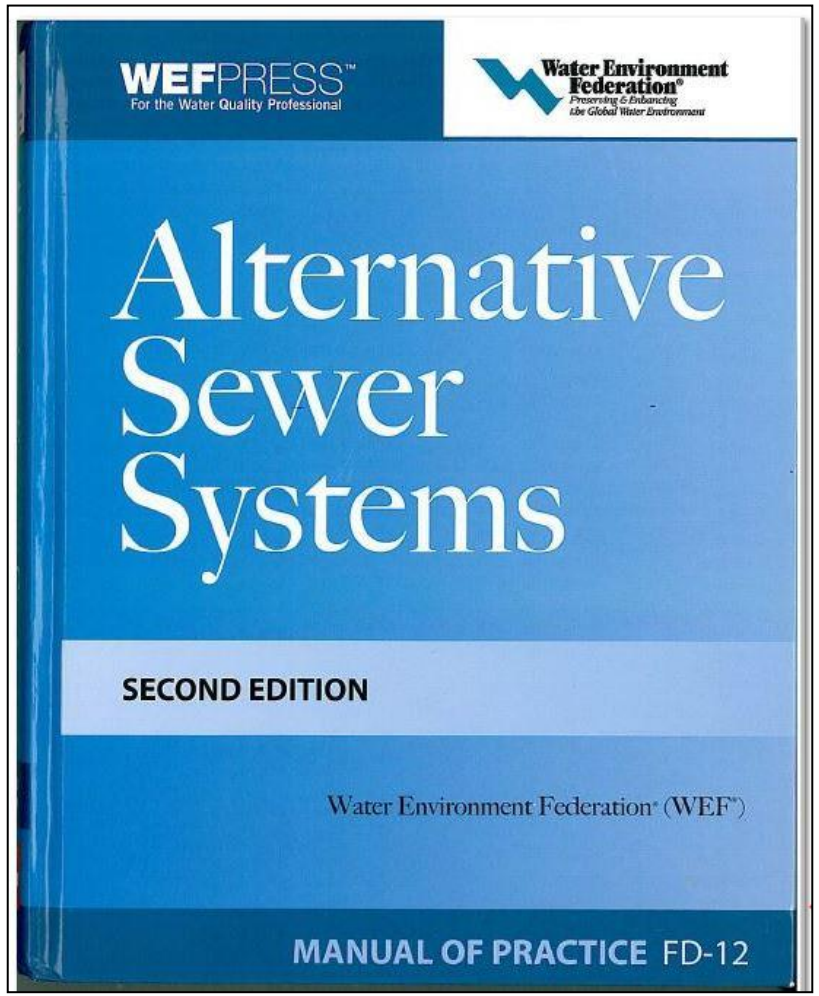


WEF Manual
WEF MOP FD-12, 2nd ed



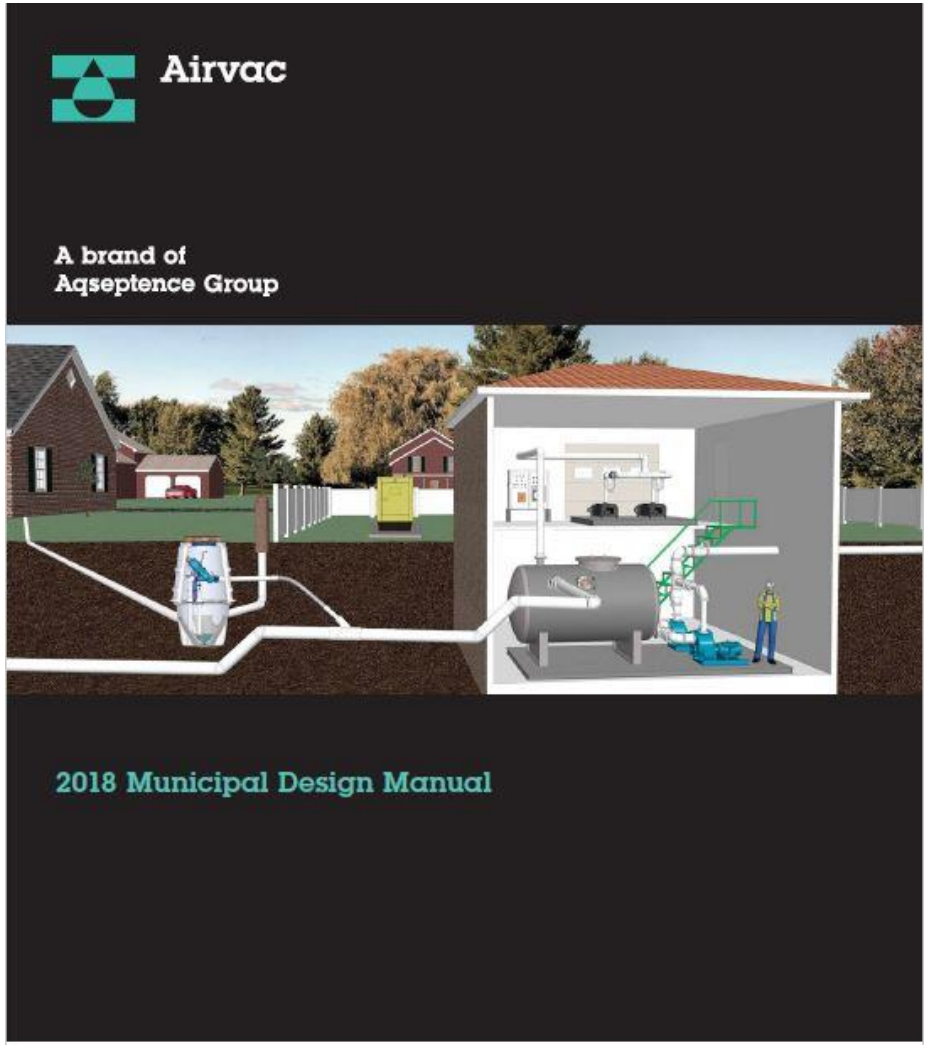
- This was an update of the 1991 EPA Manual
- Includes chapters on Low-pressure sewers, vacuum sewers and small-diameter gravity sewers
- This was published in 2008
- The content is still mainly relevant although some things have changed in each of the technologies

WEF Manual
WEF MOP FD-12, 2nd ed



- Contains the most current information on vacuum sewers
- Vacuum chapter authored by Rich Naret, P.E. (Airvac)
- Includes sample regulations

Do’s & Don'ts
Vacuum Sewer Design



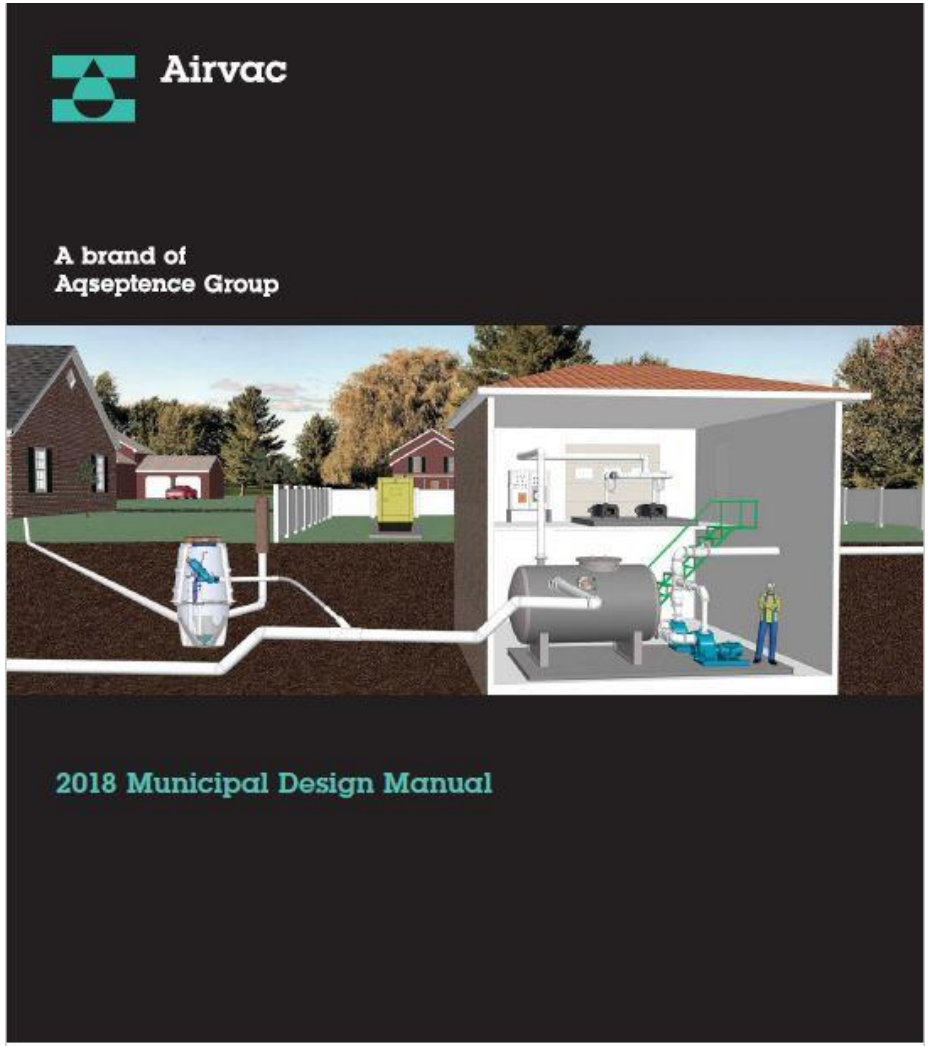
Airvac’s 2018 Design Manual contains all the design criteria needed to complete the design

There are tables at the end of each chapter summarizing the “do’s and don’ts” associated with that particular chapter

Airvac Design Manual

Chapters include:

- Introduction
- Design Flows
- Vacuum Station Design
- Vacuum Main Design
- Valve Pits
- Buffer tanks
- System Alarm & Monitoring
- Airvac Services



Review
Why vacuum sewers?

Airvac

What are some reasons why you should consider vacuum sewer systems?

1. Lower Construction cost
    1. Reduce trench depth and width
    2. Eliminate manholes in streets
    3. Eliminate lift stations

2. Less maintenance than other alternative sewers

3. Operates during power outage

4. No odors as it’s a closed system

5. No exfiltration / leaks to the environment

6. Less disruptive and safer construction

Review
Why vacuum sewers?

Airvac

What are the three main components of a vacuum sewer system?

Valve pits, vacuum mains and vacuum station

How can vacuum sewer systems save money?

Vacuum sewers save money where excavation costs of gravity sewers is high (50+ homes, flat terrain or rolling hills, high water table, rock or unstable ground, etc.)

What are some environmental benefits of using vacuum sewer systems?

Elimination of I/I is possible
No leaks to the environment even if a sewer pipe breaks
Routing flexibility saves trees & shrubs
Minimal operator contact with sewage
Potential lower energy consumption

Review
Benefits and Advantages of Vacuum Sewers

Airvac

What are some other benefits of installing vacuum sewer systems?

- Minimal impact on local traffic and businesses especially during construction
- No confined space or trapped gasses issues during repairs.
- Minimal exposure of employees to sewage
- Best system in areas prone to flooding, heavy onshore flows and high groundwater
- Standby generator at Vac Station allows operation thru catastrophic weather
- Excellent solution for seasonal flow variation such as resort areas
- Immediate leak detection and quick location avoids environmental problems
- No line blockages as materials moves thru lines at 15-18 fps
- All mains are PVC or PE which can flex in shifting ground
- Only 1 source of power (no electrical homeowner service upgrade)
- Up to 4 homes can be hooked to valve pit

Review
Benefits

Airvac

What are some other benefits of installing vacuum sewer systems?

The system is designed to run during flooding, freezing, blizzards, power outages, heavy onshore flows, hurricanes and other catastrophic weather

- Safety during construction
- Odor and corrosion minimized
- O&M costs favor larger projects w/ est. valve repair costs at $50-100 every 10-15 years
- Since system utilizes air intake, there is aerobic action on sewage prior to treatment
- Minimization of sewage discharge as system will pull liquid in rather than leak sewage out
- Sewage build up in lines is eliminated due to scouring action in lines
- Only electrical connection is at the Vac Station where there is standby back up generator
- Grease and Sand do not affect operation of the Valves or Mains.
- Grease and Sand do not affect any mechanical parts of the system

Airvac

Other applications & Industrial Systems

Airvac

A brand of
Aqseptence Group

Vacuum Liquid Conveyance Systems

Airvac

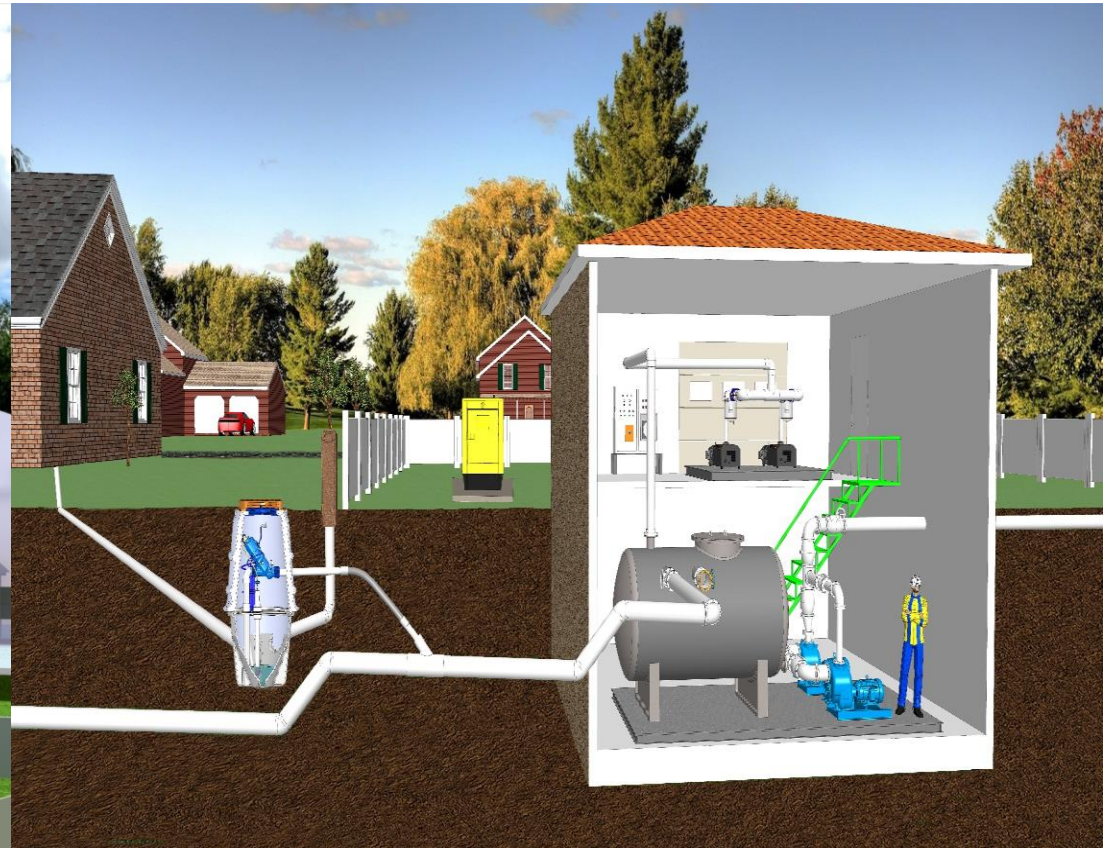
Technology Applications

- FDA Regulated and Food Processing Facilities
- Manufacturing Sites (Steel, power & Chemical Plants)
- Brownfield Site Construction
- Green and LEED Projects (Solvis & Calamigos)
- Stadiums, exhibition halls & Arenas
- Transportation: Trains, Planes, Cruise Ships
- Municipal Sewer Systems

Vacuum Liquid Conveyance Systems

Municipal and/or Industrial Commercial

Airvac



Case Study for Outdoor Industrial

Airvac

Eli Lilly-Eco Services (Solvay) - Kimberly Clark (underground)

Background

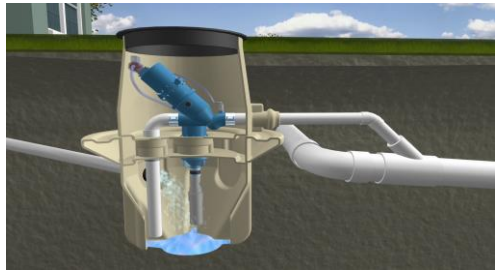
- Major firms in pharmaceuticals, chemicals & manufacturing
- Locations in Indiana, Louisiana and Alabama
- Systems boast longevity and reliability. KC installed in 1972.

Situation

- Excavation of these older sites was not safe or practical
- Site challenges included high water table, underground hazards: unknown utilities, buried chemicals and areas of high truck traffic subject to frequent ground shifting
- Brownfields site alternative for wastewater conveyance system

Solution

- Vacuum sewage systems tie in multiple buildings
- The system conveys all wastewaters (Black & Gray)
- Eco since 1979, KC since 1972 & Lilly since 1981



How It Works
Indoor Industrial & Commercial Systems

Airvac

https://www.youtube.com/watch?v=MSEaseApvzE

Case Study for Pharma Cleanroom

Airvac

Merck (Cleanroom) – FDA Validated Environment

Background

- One of the largest vaccine manufacturing sites in world (BSL-1)
- Location undergoes frequent renovation
- Syringe Washing operation in Cleanroom (Gardasil, Hep C)
- Needed wastewater conveyance system to separate streams

Situation

- Cleanroom in tight space would not allow gravity system
- Access to area limited & many obstacles in place
- Zero tolerance system leaks & no room for dual containment

Solution

- Piping & system controllers placed in walls/ceilings/attics
- Separation of chemical & biological streams in 3 vats
- Single vacuum source maintains negative pressure - no leaks
- No Dual Containment piping necessary
- Merck collaborated on a customized touch screen system for all controls of the vacuum wastewater system in the Clean Room which includes remote monitoring
- System has been in operation since 1992

Case Study Entire Building

Airvac

Roche-Basel, Switzerland (Labs & R&D)

Background

- New 10 floor facility w/ modular design for frequent changes
- 6 floors above and 4 floors below ground
- Over 70 small labs & 4 large full floor labs, office, R&D
- High visibility state-of-art campus in downtown Basel

Situation

- Areas can be changed from office to lab to R&D
- All furniture, basins are movable
- Moves allow for easy hook ups and change outs
- S3 Level (BSL 4) in certain areas includes air burned

Solution

- 270 vacuum floor drains installed allow optional usage
- 12 autoclaves in basement also on vacuum
- 2 vacuum stations supply negative pressure for building
- System can handle higher temperature and ph liquids also

Case Study Consumer Products

Airvac

L'Oreal Cosmetics – Clark, NJ (Gilbane Construction)

Background and Situation

- Gravity drainage system not practical within existing & new building
- Owners did not want to disturb floor slab
- Phase 1 of potential 2 phase vacuum wastewater solution
- Needed flexibility for later building expansion / renovation
- Areas include R&D and Pilot Plant Operations
- Vacuum Floor Sumps, Sumps, Valves with R360 Vac Station
- Original Design by SNC-Lavalin with final D/C by Gilbane
- L'Oreal will be seeking LEED Silver certification for building
- Construction was completed in March 2021

Case Study-Indoor Sanitation

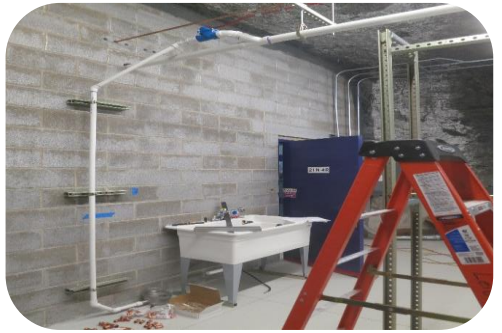
Airvac

Leidos Corporation-Boyers, PA (R&D Lab)

Background
- Facility is located 220 feet underground
- Leidos needed a highly secure R&D facility for experiments
- Former division of SAIC Corporation
- Location is part of Iron Mountain high security facility

Situation
- Due to facility depth, no gravity option on wastewater
- Minimization of wastewater discharge due to cost
- Sustainable solution that recycles almost all water on site

Solution
- The vacuum system hooked to bioreactor treatment
- All lab & gray water, & most of black water recycled on site
- Vacuum toilets capture toilet plume as air/water drawn downward
- Small filter sludge disposed offsite



Toilet Plume-Indoor Sanitation

Airvac

- Many public restrooms lack toilet lids on gravity toilets
- Upon flushing a germ filled aerosol is created and spread
- Situation is compounded by lack of proper ventilation
- Air hand dryers worsen the condition and help to spread germs
- Especially worrisome with rise of Covid-19

Toilet Plume-Indoor Sanitation

Airvac

- Vacuum toilets are under negative pressure
- Upon flushing water, air and particles are pulled downward
- These are the systems we typically see on Cruise Ships
- Moreover, vacuum toilets use only one quart per flush
- Vacuum toilets are a good option for water conservation especially in projects such as LEED and Green Building design