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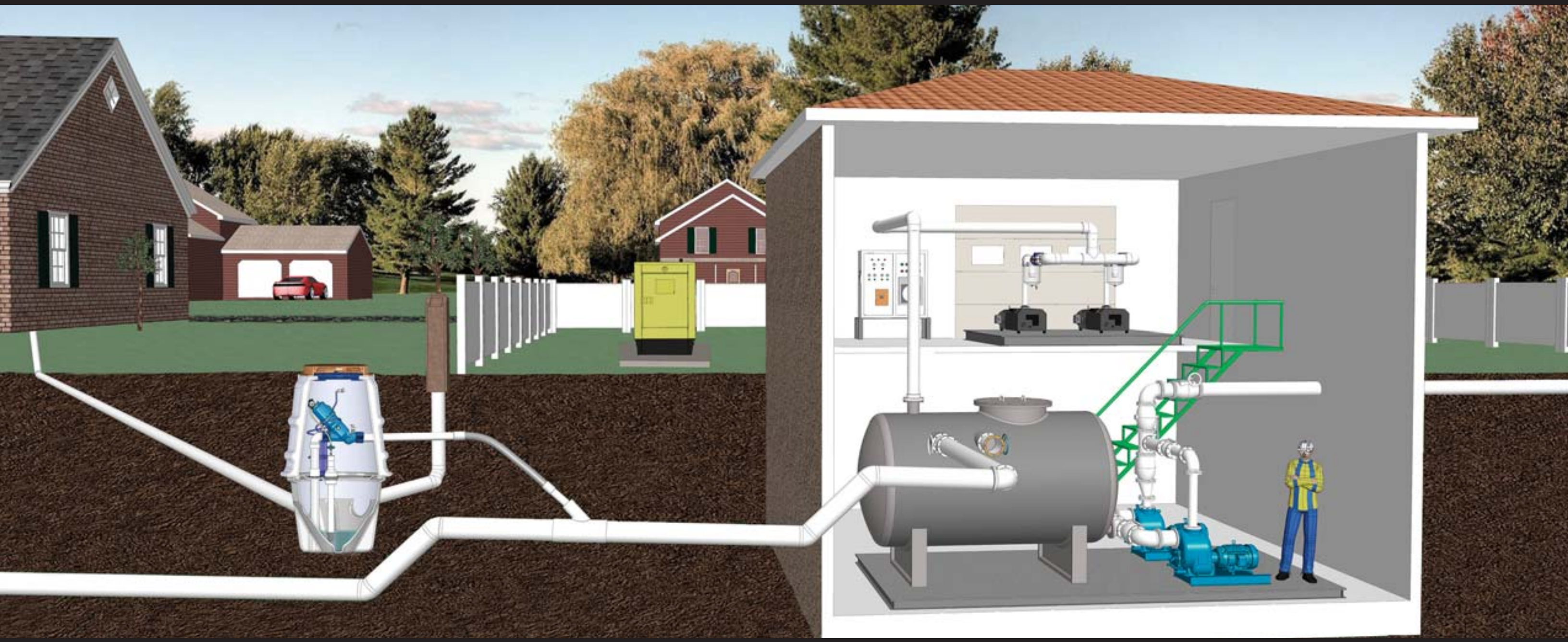

2018 Municipal Design Manual

Airvac

The World Leader in Vacuum Sewer Technology

DISCLAIMERS

***Airvac is not an engineering firm**, and cannot and does not provide engineering services. Airvac reviews the design, plans, and specifications for a project only for their compatibility with Airvac's vacuum products, and accepts no responsibility for the overall project design. Any information provided to project engineers is provided solely to assist the engineer in designing and engineering and maintaining an overall system that can utilize Airvac vacuum products.*

***Airvac is not an approval agency** and never "approves" a product. However, as the industry leader in vacuum sewer technology, Airvac understands that our clients and their engineer look to us for guidance. Toward this end, Airvac uses a progressive comfort level system to provide our clients with guidance on the use of a particular product in their system. Generally speaking this means factory testing followed by field testing followed by limited use in an actual system and eventually widespread use. It isn't until a product has been successfully used for a significant amount of time in a significant number of projects that AIRVAC will rate a product as acceptable for use in a vacuum system.*

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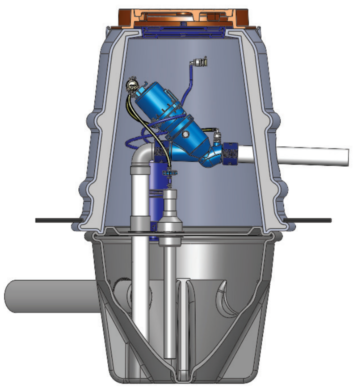

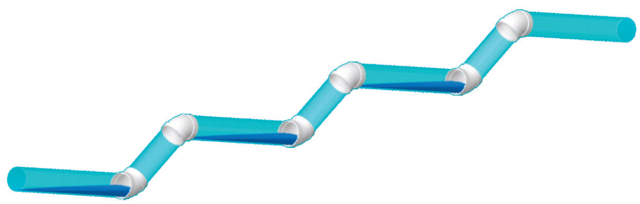

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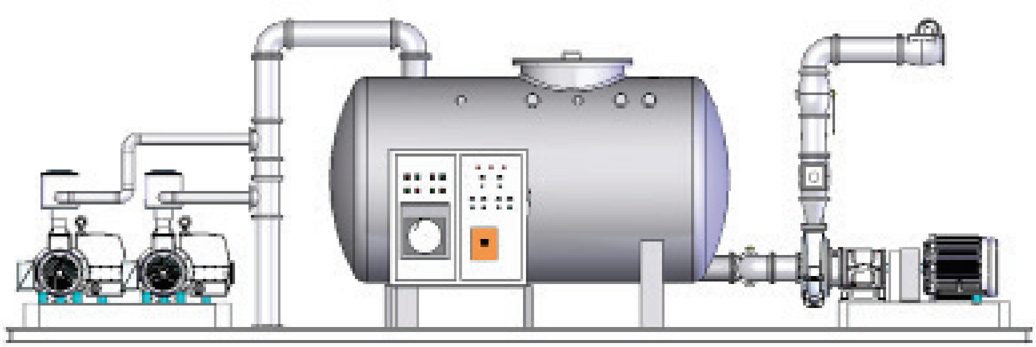

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CHAPTER 1
INTRODUCTION

The design guidelines contained in this manual are intended for buried vacuum sewer systems serving municipalities or land developments that utilize Airvac's 3-in. vacuum valve. For indoor vacuum piping systems and applications that utilize vacuum valves smaller than 3-in. and/or vacuum toilets, contact Airvac's Engineering Department for application-specific design guidelines.

A. HISTORY OF VACUUM COLLECTION SYSTEMS

Vacuum sewers were first used in Europe in 1882. However, it has been only in the last 50 years or so that vacuum transport has been utilized in the United States. During this time, the use and acceptance of vacuum sewers have expanded greatly. Entering 2018, 340 Airvac vacuum systems were in operation in 30 U.S. states. Worldwide, Airvac has more than 1000 installations in 36 countries.

This technology is also recognized in two industry publications: The United States Environmental Protection Agency (EPA), publication number EPA/625/1-91/024, the *Manual For Alternative Wastewater Collection Systems* and the Water Environment Federation (WEF) *Alternative Sewer Systems, 2nd ed.; Manual of Practice No. FD-12.* The design criteria presented in both manuals are based on Airvac.

B. GENERAL DESCRIPTION

Vacuum sewers are a mechanized system of wastewater transport. Unlike gravity flow, vacuum sewers use differential air pressure to move the sewage. A central source of power to operate vacuum pumps is required to maintain vacuum on the collection system (See Figure 1-1).

The vacuum sewer system requires a normally closed vacuum/gravity interface valve at each entry point to seal the lines so that vacuum is maintained. The interface valves; located in a valve pit, open when a predetermined amount of sewage accumulates in the collecting sump. The resulting differential pressure between atmosphere and vacuum becomes the driving force that propels the sewage towards the vacuum station.

Vacuum sewer lines are designed to maintain a generally downward slope toward the vacuum station so essentially, they are a vacuum assisted, gravity flow piping network.

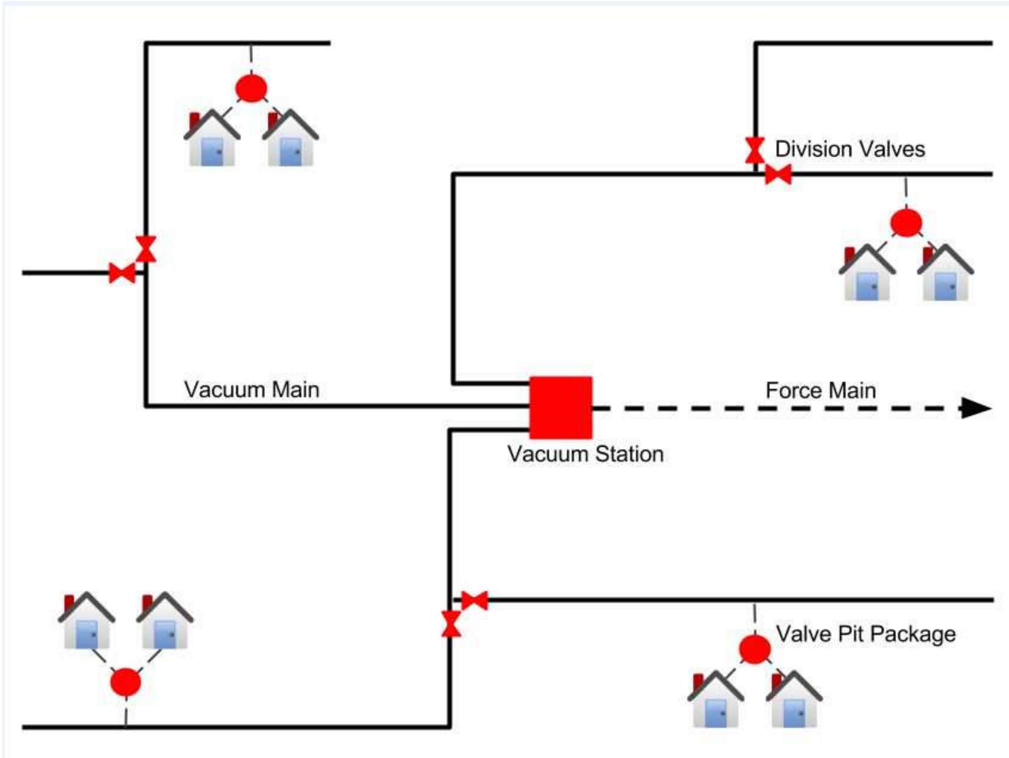


FIGURE 1-1: TYPICAL LAYOUT

C. VACUUM TRANSPORT PROCESS

When a sufficient volume of sewage accumulates in the valve pit sump, the vacuum valve will open. Differential pressure forces the sump liquid content and atmospheric air into the vacuum main at high velocities. The liquid continues downstream until friction and gravity eventually bring it to a rest at a low spot (bottom of a lift) in the piping network. Another valve cycle, at any location upstream of the low spot, will cause the liquid to continue its movement toward the vacuum station.

Sawtooth profile

The sawtooth profile ensures that an open passage of air between the vacuum station and the interface valves is maintained throughout the piping network. This provides the maximum differential pressure at the interface valves to insure self-cleansing of the valves as well as maximum energy input to the vacuum mains.

When the liquid comes to rest at the base of various lifts, it does not come in contact with the crown of the pipe and therefore does not seal the pipe (Figure 1-2). Should the lift be sealed for any reason, liquid would become suspended within the lift and an associated vacuum loss incurred.

The Airvac design philosophy includes an accounting of all lifts for all flow paths within a system and the associated potential vacuum loss incurred. The static loss limit assures that sufficient vacuum will be available for valve operation in the event of an air to liquid imbalance.

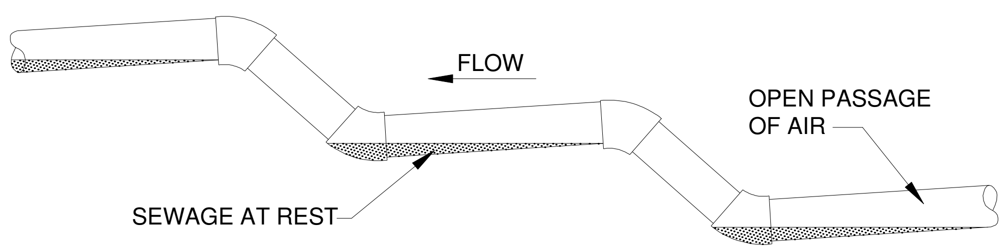


FIGURE 1-2: SAWTOOTH PROFILE

<u>Air to Liquid ratio (A/L ratio)</u>

Vacuum systems are designed to operate on two-phase (air/liquid) flows with the air being admitted for a time period twice that of the liquid. Open time of the Airvac valve is adjustable; hence, various air to liquid (A/L) ratios are attainable. Initial velocities of 15 to 18 ft/sec are attained in the vacuum main which provides scouring.

The ability of the vacuum main to quickly recover to the same level of vacuum that existed prior to the cycle, is commonly referred to as “vacuum response”, and is very important in vacuum sewer design. Vacuum response is a function of line length, pipe diameter, number of connections, and the amount of lift in the system.

<u>Back-surge</u>

Sewage admitted to a vacuum main through an Airvac valve initially moves in two directions. Approximately 80% flows toward the vacuum station and 20% flows in the opposite direction. When the back-surge slows, all the flow moves toward the vacuum station (see Figure 1-3). The vacuum transport process is clearly demonstrated at the Airvac Demonstration Rig at Airvac’s factory.

The back-surge would become 50% if a tee fitting were used instead of a wye fitting which would result in a less efficient system. For this reason, a tee is never used in a vacuum system.

At the time this manual was published, Airvac's R&D Department was working on a special check valve for vacuum mains that would prevent back-surge resulting in more efficient liquid transport.

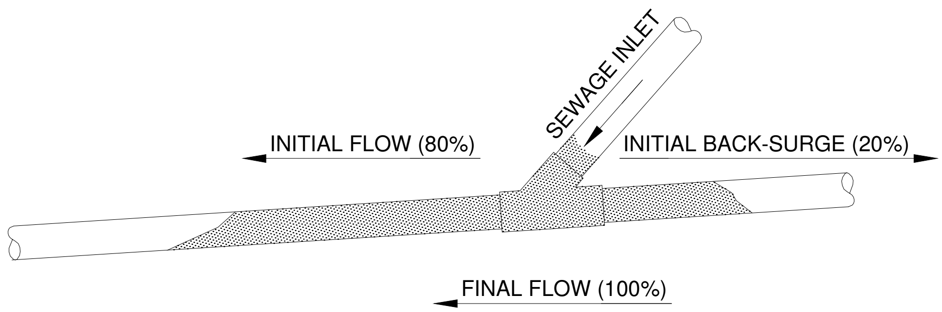


FIGURE 1-3: TYPICAL BACKSURGE

D. MAJOR SYSTEM COMPONENTS

There are three (3) major system components: the valve pit, the vacuum main piping, and the vacuum station. These are described on the following pages.

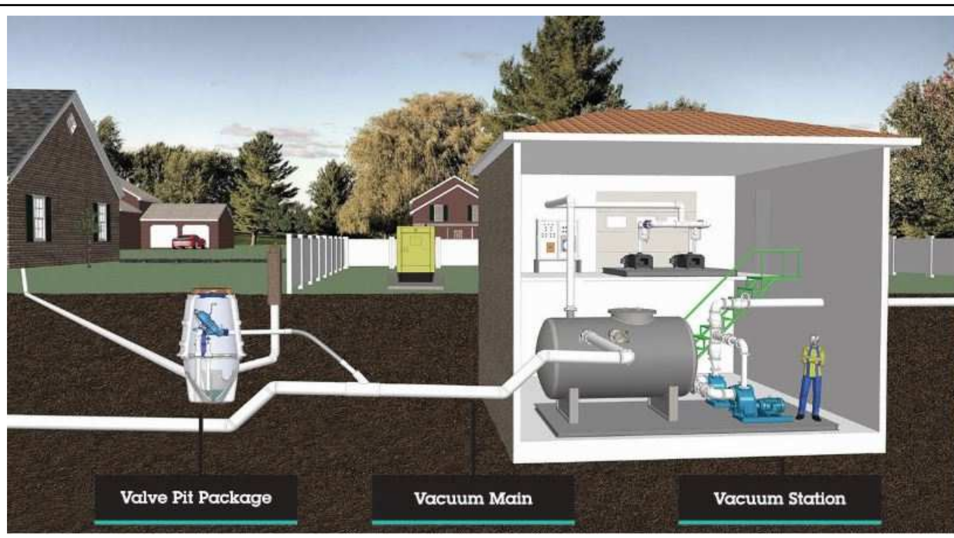


FIGURE 1-4: MAJOR SYSTEM COMPONENTS

Valve Pit

The valve pit houses the vacuum valve and provides the interface between the vacuum system and the house. The sump portion of the valve pit is used to accept the wastes from the house.

Airvac has four styles of valve pits; a 1-piece molded PE pit, a 2-piece molded PE pit, a 2-piece cold weather molded PE pit and a 2-piece PE/fiberglass pit. In all styles, there are two (2) separate internal chambers; an upper chamber that houses the vacuum valve and a bottom chamber that is the sump into which the building sewer is connected. These two chambers are sealed from each other. All Airvac valve pits are capable of withstanding H20 traffic loads.

The vacuum valve operates without the use of electricity. The Airvac 3-in. vacuum valves are manufactured of materials suitable for handling sewage. The valve is entirely pneumatic by design, and has a full 3-inch opening size. Some states have made this a minimum size requirement, as this is slightly larger than the throat diameter of the standard toilet.

The vacuum valve provides the interface between the vacuum in the collection piping and the atmospheric air in the building sewer. System vacuum in the collection piping is maintained when the valve is closed. With the valve opened, system vacuum evacuates the contents of the sump.

Once the contents of the holding sump have been evacuated, atmospheric air is admitted through the vacuum valve to provide propulsion to the liquid. The source of atmospheric air is either a 6-in. air-terminal that is connected directly to each valve pit (recommended) or a 4-in. air-intake that is placed on each house gravity line (optional).

In the recommended method, the 6-in. air-terminal is located a short distance from the valve pit and is connected to the pit via 6-in. piping to one of the four (4) openings in the sump. Airvac prefers that no sewage be permitted to enter this air-only line.

With the optional method, the 4-in. air-intake is installed downstream of all the house traps. This will circumvent the potential problem of inadequate house venting which results in trap evacuation. Local codes may dictate exact locations. In cold climates, Airvac recommends placing the air-intake on each gravity line connected to the sump at least 20 feet from the vacuum valve.

If local codes allow, a backwater valve on the homeowner's building sewer may be used. With most backwater valves, positioning is critical to ensure proper operation of the Airvac valve (see Chapter 6); however, by using a normally opened type backwater valve, this concern can be alleviated. Airvac should be consulted before such a device is installed.

Vacuum Piping

The following terms are used throughout this manual:

- Vacuum main: any single vacuum sewer line originating from the vacuum station and extending to the far reaches of the collection system

- Branch line: any vacuum sewer line that connects to a vacuum main

- Vacuum service lateral: the 3-in. piping from the valve pit to a vacuum main or branch line. This consists of 2 parts: the 3-in. Airvac flexible connector and the 3-in. rigid PVC vacuum lateral.

Installation of vacuum sewer piping is depicted in numerous details shown within this manual; additional construction details are available upon request.

Airvac sewers are laid in a saw tooth profile. When Airvac sewers are installed at 0.2% fall in flat land, the trench depth increases 1 foot every 500 feet. Profile changes, also called lifts, may be used to bring the sewer invert back to the commencing level, keeping the trench depth to a minimum. Where the natural ground profile has a fall greater than 0.2% in the flow direction, the vacuum sewer profiles follow those of the ground with no profile changes.

SDR 21 PVC is the most commonly used pipe, although PE pipe has also been used. Schedule 40 is acceptable, but with the advent of the Rieber style gasket, this is rarely used. Typical sizes are 3-in., 4-in., 6-in., 8-in., and 10-in. In unusually large systems the use of 12-in. pipe may be required; however, several modifications to the normal vacuum station components are required. Consult Airvac for guidance.

Schedule 40 PVC *pressure-rated* fittings are used. Fittings include wyes (connecting service laterals to branches or connecting branches to mains), bends/ells (changes in direction and lifts), and concentric reducers (changes in main size). Tee fittings are not used for vacuum sewers.

Pipe and fitting joints are either solvent welded or rubber ring type joints. ***Not all rubber ring pipe joints are suitable for vacuum service and engineers should require a guarantee and test certification from the manufacturer.***

Division valves are installed in branch and main lines to allow portions of the piping system to be isolated for troubleshooting and maintenance. These valves are typically resilient-wedge gate valves using mechanical joint connections with transition gaskets to PVC pipe that are suitable for underground vacuum service.

Vacuum Station

The vacuum station is the heart of the vacuum collection system. The equipment installed is similar to that of a conventional sewage pumping station or lift station, except vacuum is applied to a sealed wet well (collection tank). Major components include the tank, sewage pumps, vacuum pumps, and a control panel.

Most modern vacuum systems utilize factory pre-fabricated station equipment mounted on skids for ease of installation. Skids are typically housed in a two-story structure with the vacuum pumps and control panel located on the top floor and the collection tank and sewage pumps on the lower floor.

Collection tanks are normally fiberglass, 316 stainless steel or carbon steel with protective coatings. The vacuum sewers terminate at this tank where vacuum is maintained automatically and transferred to the sewer system.

Duplicate sewage discharge pumps are used, with each pump capable of pumping design peak flow. Horizontal non-clog or self-priming centrifugal or dry pit submersible pumps can be used.

Two or more rotary claw type vacuum pumps, each capable of an ultimate vacuum range near 24-in. Hg, are used. Horsepower of the rotary claw vacuum pumps range from 7 ½ to 15 hp. Rotary vane type pumps, capable of a higher ultimate vacuum near 29-in. Hg. may also be used but are no longer the Airvac standard. Horsepower for rotary vane pumps range from 7 ½ to 40 hp.

Check valves for discharge pumps feature soft seats with outside weights and levers; vacuum pump inlet check valves are also fitted with soft seats.

Typical electrical controls include:

- 4-20ma pressure transmitters
- Capacitance, conductance or radar type liquid level controls
- PLC or relay logic
- IEC or NEMA Motor starters
- Automatic alternators for pump cycling
- Hour run meters
- Touchscreen Operator Interface
- Remote access and troubleshooting module
- SCADA alarm system or solid-state telephone alarm system
- A seven (7) day programmable circular vacuum chart recorder with digital totalizers or a graphical data logger

Many systems utilize existing portable generators for emergency power while others have permanently installed back up generators.

See Chapter 4 for design parameters and details of vacuum stations.

E. APPLICATIONS

The consulting engineer usually drives the community's choice of collection system type during the planning stages. This choice is normally based on the results of a cost-effectiveness analysis.

Where used
Below are the general conditions that are conducive to the selection of vacuum sewers.

- Unstable soil
- Flat terrain
- Rolling hills with small elevation changes
- High water table
- Restricted construction conditions
- Rock
- Urban development in rural area
- Sensitive eco-system

Advantages-Construction
The advantages of vacuum collections systems may include substantial reductions in water use, material costs, excavation costs and treatment expenses. In short, there is a potential for overall cost-effectiveness. Specifically, the following advantages are evident:

- Small PVC pipe sizes (3-in., 4-in., 6-in., 8-in., and 10-in.) are usually used.

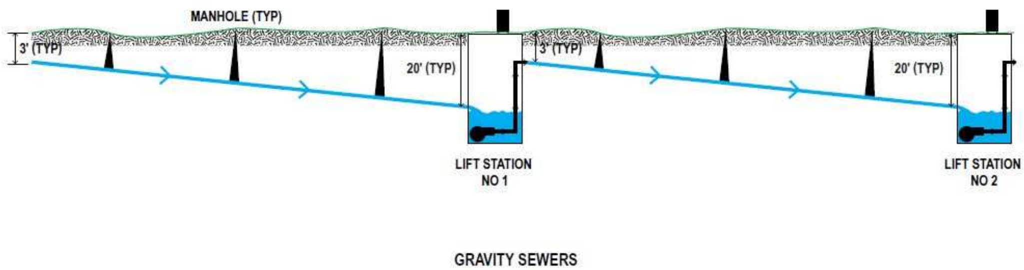
- No manholes are necessary.

- Field changes can easily be made as unforeseen underground obstacles can be avoided by going over, under or around them.

- Installation of smaller diameter pipes at shallow depths eliminates the need for wide, deep trenches reducing excavation costs and the duration and severity of community/environmental impacts.

- Only one source of power, at the vacuum station, is required. No on-lot power demands exist at the valve pit locations.

- One vacuum station can replace up to 6 or 7 gravity lift stations while keeping trench depths to a minimum.



Gravity sewers typically require multiple lift stations. It is not uncommon for vacuum sewers to replace 6 or 7 gravity lift stations while keeping trench depths to a minimum

FIGURE 1-5: MULTIPLE LIFT STATIONS - GRAVITY

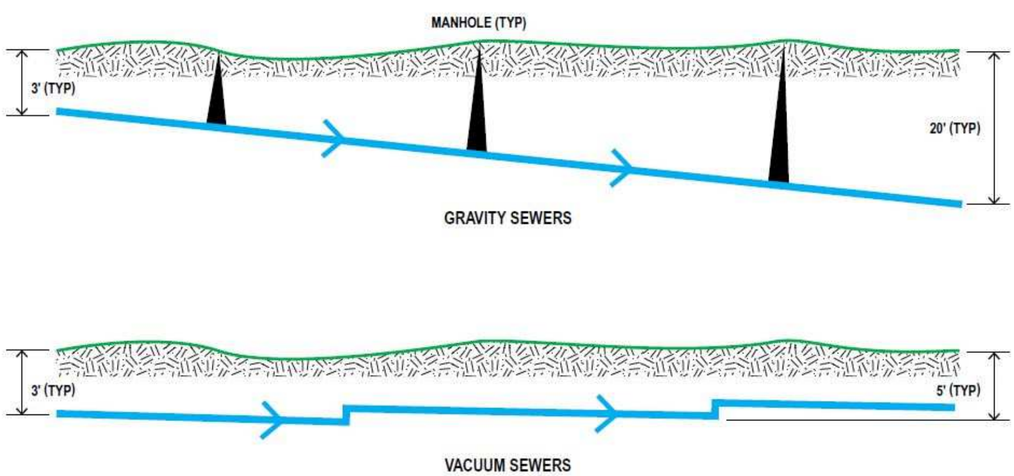


FIGURE 1-6: VACUUM AND GRAVITY PROFILES

Advantages-Operation (general)
There are several operating advantages to using vacuum sewers as described below:

- High scouring velocities are attained, reducing the risk of blockages and keeping wastewater aerated and mixed.

- Elimination of the exposure of maintenance personnel to the risk of H_2S gas hazards.

- The system will not allow major leaks to go unnoticed, resulting in reduced environmental damage from exfiltration of wastewater.

- The elimination of infiltration permits a reduction of size and cost of the treatment plant.

- The air/sewage mixture enters sewers at high velocity, and the air provides some pretreatment to the sewage inside the vacuum sewers.

Advantages-Operation (in hurricane prone areas)
There are several advantages to using vacuum sewers for hurricane prone areas. System operators of actual systems that have experienced hurricanes report the following advantages:

- Because they are sealed, vacuum systems eliminate the threat of massive I&I and sewage spills. In coastal areas where 1 vacuum station typically replaces 7 or 8 lift stations, this means less hurricane preparation is required. This also means that the treatment plant will not be overwhelmed.

- All vacuum stations have either a fixed or portable generator, which ensures uninterrupted service to the customer.

- The maintenance staff is not exposed to the severe weather as the generators automatically start during a power outage.

- If water level rises to the point where the air-intakes are in danger of flooding, sections of the system or the entire system can be turned off, thus preventing damage to system components.

CHAPTER 2
DESIGN FLOWS

A. BASIS OF DESIGN

Many of the major vacuum system components are sized according to peak flow, expressed in gallons per minute (gpm). Peak flow rates are calculated by applying a peaking factor to an average daily flow rate and then converting to gpm.

B. AVERAGE DAILY FLOW

Average daily flow rates are based on one of the following methods:

1. Documented average daily flow for the area being served *(preferred method)*. Water use records are typically used for this purpose.

2. 100 gallons/person/day x population *(Ten States Standards)*. Most approval agencies will accept published U.S. Census Bureau data.

3. 75 gallons/person/day x 3.5 per/house x # of houses *(EPA & Airvac standard)*

C. PEAKING FACTOR

The peaking factor suggested by the design firm will be used, with one exception: the minimum peaking factor should never be less than 2.50. If none is suggested, the Airvac standard peak factor of 3.50 will be used.

As a guide to establishing a peak factor, the following Ten States Standards formula can be used:

$$\frac{18 + \sqrt{POPULATION/1000}}{4 + \sqrt{POPULATION/1000}}$$

For example, if the service area has a population of 1,200, the peaking factor would be:

$$\frac{18+\sqrt{1.2}}{4+\sqrt{1.2}} = 3.75$$

Table 2-1 shows peak factors for various populations. Please note that these are not the exact figures that would be returned by the formula but rather are rounded figures for presentation purposes only.

Table 2-1

Peak Factors
Based on Ten State Standards formula

Population	Peak factor
100	4.25
500	4.00
1,200	3.75
2,500	3.50
5,000	3.25
9,000	3.00

D. PEAK FLOW

Applying the peak factor to the average daily flow rate and converting to gpm will yield the peak flow to be used as the basis of design.

Q_a /1440 min/day x PF = Q_{max}

where: Q_a = Ave daily flow (gpd)
PF = Peak factor
Q_{max} = Peak Flow (gpm)

Example: Using documented flows & peak factor supplied by design firm

Q_a (Average daily flow): 100,000 gpd
Peak factor: 3.25

Q_{max} = 100,000 gpd/1440 min/day x 3.25
Q_{max} = 225 gpm

Example: Using Ten State Standards flow rates & peak factor

Average daily flow rate: 100 gpcd
Population: 1,200 persons
Peak factor 3.75

Q_a = 100 gpcd x 1,200 persons = 120,000 gpd

Q_{max} = 120,000 gpd/1440 min/day x 3.75
Q_{max} = 313 gpm

Example: Using Airvac standards

Average daily flow rate: 75 gpcd
Persons/house 3.5
houses: 400
Peak factor: 3.50

Q_a = 75 gpcd x (3.5 per/hse x 400 hse) = 105,000 gpd

Q_{max} = 105,000 gpd/1440 min/day x 3.50
Q_{max} = 255 gpm

E. INFILTRATION

The vacuum system is a sealed system that eliminates ground water infiltration from the piping network and the interface valve pits. However, ground water can enter the system from leaking house plumbing or as a result of building roof drains being connected to the plumbing system. ***It is therefore important for designers to consider methods of eliminating ground water from the house plumbing system during the design phase of a project.***

F. FLOW ENTERING VIA PUMPS

For purposes of vacuum design, any flow that enters the vacuum system via a pump should be expressed in terms of the actual discharge pump rate rather than the standard peak flow rate from the house.

G. FUTURE GROWTH

While vacuum systems have some inherent reserve capacity, it is recommended that design engineers consider future growth when sizing the vacuum system components. Growth anticipated over a 20 or 30-year period is typical; however, the design engineer should follow regulatory and funding agency guidelines.

CHAPTER 3
VACUUM STATION – PRELIMINARY SELECTION

A. VACUUM STATION DESCRIPTION-GENERAL

Vacuum sewer systems require a central vacuum station which functions like a gravity lift station. Major components include:

- Collection tank
- Vacuum pumps (2 or more)
- Sewage pumps (2)
- Control panel.

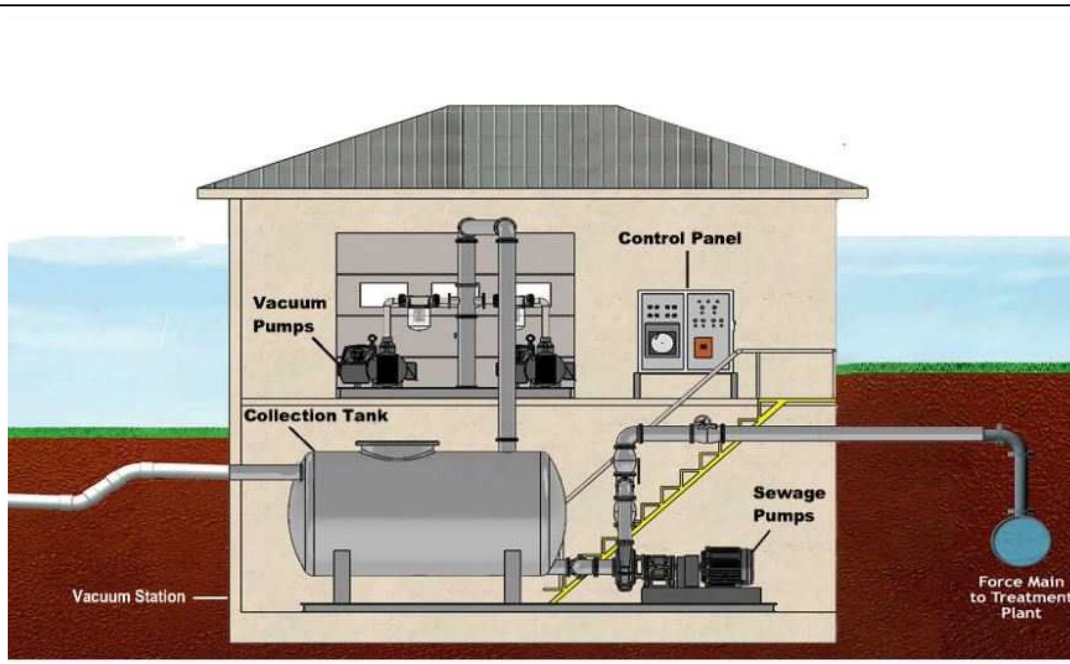


Figure 3-1: General depiction of a 2 story over/under Vacuum Station

There are several ways that the equipment can be configured depending on the final design. In some case it may be possible to have all equipment located on a single level and housed in a structure on grade, partially buried or with a basement. In other cases, a 2 story, over/under configuration as depicted above is required.

B. VACUUM STATION MAJOR COMPONENTS

Collection Tank – Either a fiberglass, 316SS or carbon steel tank, internally and externally epoxy coated is used. Tanks are designed with a working pressure of 20-in. Hg and tested to 26-in. Hg for 5 minutes and 24-in. Hg for 4 hours. For direct-bury applications, fiberglass tanks with the same pressure rating are used.

Sewage Pumps – Duplicate horizontal, non-clog or duplicate self-priming centrifugal or dry pit submersible pumps are used.

Vacuum Pumps – Two or more rotary claw type vacuum pumps capable of an ultimate vacuum range of 24-in. Hg are used. *See Chapter 4 for a discussion on the Busch vacuum pumps used by Airvac.*

Control Panel - Typical electrical controls include PLCs or relay logic, 4-20ma vacuum transmitter, liquid level controls, IEC or NEMA motor starters, automatic alternators for pump cycling, hour run meters, operator interface touch screen, SCADA integration or a solid-state telephone alarm system, remote access and troubleshooting module, a solid-state telephone alarm system, and a 7-seven day circular vacuum chart recorder with digital totalizers or a graphical data logger.

C. PRELIMINARY VACUUM STATION SELECTION

Airvac offers several different types of vacuum stations. The type of vacuum station used is a function of the project size in terms of connections and peak flow.

Table 3-1
Vacuum Station Selection

CONNECTIONS Range	Max	PEAK FLOW Range	Max	STATION TYPE
25 - 100	100	15 - 65 gpm	65 gpm	Containerized Ver 1
100 - 300	300	65 - 200 gpm	200 gpm	Containerized Ver 2
120 - 235	235	75 - 150 gpm	150 gpm	PacVac - Ver 1 or Ver 2
235 - 550	550	150 - 350 gpm	350 gpm	PacVac - Ver 3 or Engineered Custom
> 550	~1600	> 350 gpm	~1000 gpm	Engineered Custom

D. CONTAINERIZED – all equipment housed in a shipping container

For customers who need an inexpensive, small vacuum station for an initial phase of a larger system, Airvac offers a small vacuum station housed in a 30-foot shipping container that has been modified for this use.

Figure 3-2: Containerized Vacuum Station

This includes an at-grade or partially buried shipping container that houses all the mechanical equipment on 1 level. All the mechanical equipment is assembled on 1 skid and mounted inside an insulated, air-conditioned shipping container and the complete unit is supplied by Airvac. The container is delivered directly to the site where it is placed on a slab on-grade, or is partially buried. The contractor connects the incoming vacuum main(s) & outgoing force main as well as brings electrical power to the building. Odor control, a valve vault and a standby generator completes the installation.

Things to consider prior to selecting the Containerized vacuum station: 100 yr flood level, static lift limits & station site conditions that may preclude the use of above ground piping.

By Airvac

All mechanical & electrical equipment including vacuum pumps, sewage pumps, collection tank, and control panel on a single skid housed in a shipping container. *Optional: Standby generator.*

By contractor

Install slab or partial buried vault, install container, site work, and furnish & install standby generator and odor control.

E. PACVAC- VER 1 – all equipment on 1 level; prefabricated building

Airvac offers several versions of a "packaged vacuum station" that includes not only the vacuum station equipment but also a prefabricated building to house it. Version 1 is ideally suited for small to medium-sized projects serving less than 235 connections and/or peak flows less than 150 gpm.

Figure 3-3: PacVac Ver 1 (Station on-grade shown)

Version 1 includes a 1-story, at-grade or partially buried prefabricated building that houses all the mechanical equipment on 1 level. All the mechanical equipment is assembled on 1 skid and is supplied by Airvac. The prefabricated building is supplied by Airvac. ***Things to consider prior to selecting Ver 1: 100 yr flood level & static lift limits.***

The complete unit is delivered directly to the site where the building is placed on a slab on-grade or partially buried. The contractor connects the incoming vacuum main(s) & outgoing force main as well as brings electrical power to the building. Odor control and a standby generator completes the installation.

By Airvac

All mechanical & electrical equipment including vacuum pumps, sewage pumps, collection tank, and control panel on a single skid. Prefabricated building to house the equipment skid. *Optional: Standby generator.*

By contractor

Install slab/basement, install the building, site work, and furnish & install standby generator and odor control. *Optional: structure to house the equipment if not provided by Airvac.*

F. PACVAC VER 2 – over/under configuration w/prefabricated building

Version 2 of PacVac contains the same equipment as Version 1 but rather than everything on 1 level, the equipment is arranged in an over/under configuration in a two-story structure with the top a prefabricated building.

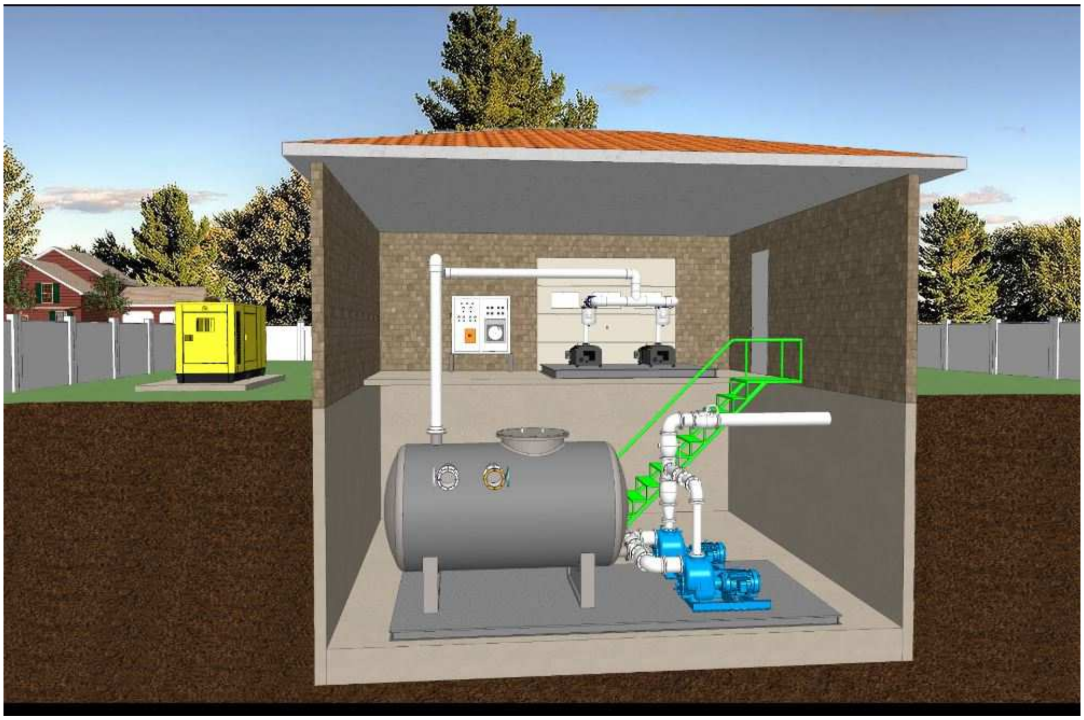


Figure 3-4: PacVac Ver 2 (Over/Under configuration)

The vacuum pumps and control panel are located on the top floor and are housed in a prefabricated building which is supplied by Airvac. The lower level basement houses the collection tank and sewage pumps. All equipment and the prefabricated building is delivered directly to the site where it is installed by the contractor after the basement has been completed. Odor control and a standby generator completes the installation.

By Airvac

All mechanical & electrical equipment including vacuum pumps, sewage pumps, collection tank, and control panel on two skids. Prefabricated building to house the equipment skid. *Optional: Standby generator.*

By contractor

Install slab/basement, install the building, site work, furnish & install standby generator and odor control. *Optional: structure to house the equipment if not provided by Airvac.*

G. PACVAC VER 3 – direct bury tank and prefabricated building

At the time this manual was published, Airvac was working on a concept for 3rd version of PacVac that would serve mid-sized projects with peak flows ranging from 150 gpm to 350 gpm. The goal is to offer a standardized vacuum station that is less expensive than those currently being built and where the contractor's installation effort is simplified and significantly reduced. The main features are:

- A 1 single story, on-grade prefabricated building complete with vacuum pumps and a control panel. Because of the higher peak flow capability, larger vacuum pumps than those in Version 1 & 2 are used.

- A direct bury fiberglass collection tank, available in 1500, 2000, 2500 & 3000-gallon sizes.

- Dry-pit submersible pumps housed in either an inexpensive, operator friendly vault or possibly housed in a fiberglass structure that is part of the collection tank itself. In the latter case, the collection tank portion will be under negative pressure and the pump vault portion will be at atmosphere. *This was under investigation at the time this manual was published.*

Shown below is the concept with the combination tank/pump vault.

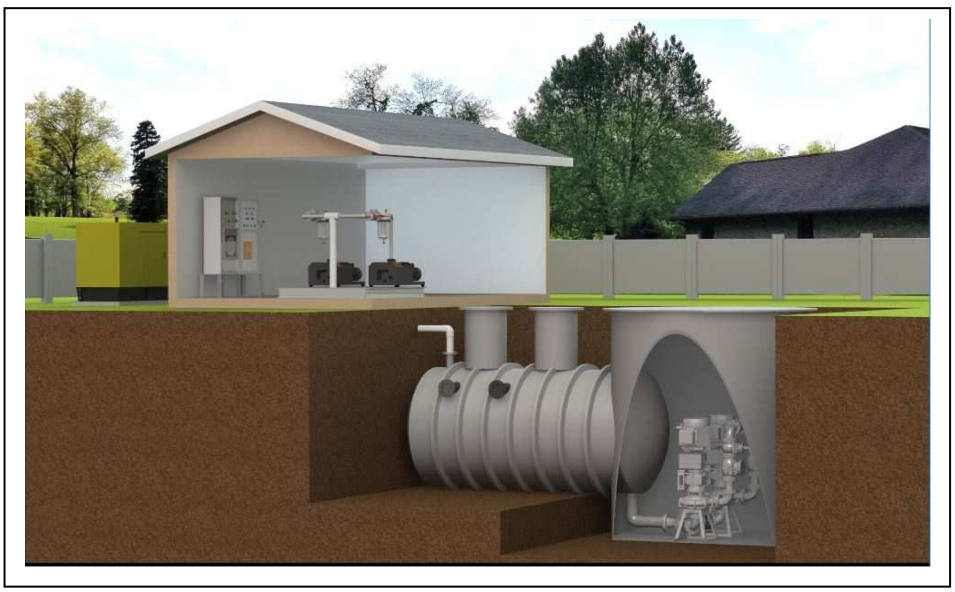


Figure 3-5: PacVac Ver 3 concept

Note that, in the absence of Version 3, either Version 1 or Version 2 could be modified to handle the higher peak flow by utilizing a larger tank and larger vacuum pumps. Or an engineered, custom vacuum station can be used as well.

H. ENGINEERED CUSTOM VACUUM STATION

Prior to the advent of the PacVac stations, vacuum stations were custom-designed with the internal equipment prefabricated and supplied by Airvac and housed in a building custom designed by an engineering firm. This concept will continue to be used for projects that are not candidates for the PacVac stations.

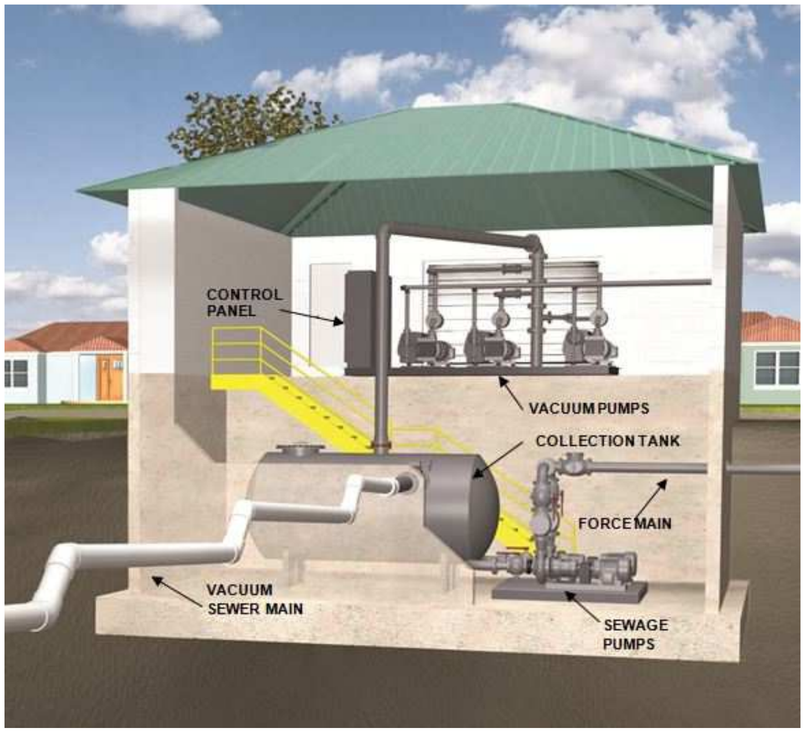


Figure 3-6: Engineered Custom station

In the engineered custom skid arrangement, the Airvac skid is typically housed in a two-story structure with the vacuum pumps and control panel located on the top floor and the collection tank and sewage pumps on the lower floor.

By Airvac

All mechanical equipment including vacuum pumps, sewage pumps and collection tank as well as electrical equipment for all pumps and the control panel.

By contractor

Site work, construct the vacuum station building, install the Airvac skid, incidental electrical and plumbing, and furnish & install standby generator and odor control.

I. VACUUM STATION MODEL NOMENCLATURE

Containerized stations

V1 - 165

- 165 — vacuum pump capacity (cfm)
- V1 — Container type (Ver 1 or Ver 2)

PacVac stations

2 - 170 M

- M — vacuum pump type (M=Mink pump; R=R5 pump)
- 170 — vacuum pump capacity (cfm)
- 2 — # of vacuum pumps

Engineered Custom stations

3 - DR 45

- 45 — Collection tank size (gal/100)
- DR — vacuum pump capacity (cfm) & type (R or M) – see table
- 3 — # of vacuum pumps

Mink pumps		**R5 Pumps**	
AM	103 cfm	AR	117 cfm
BM	165 cfm	BR	170 cfm
CM	277 cfm	CR	305 cfm
DM	353 cfm	DR	455 cfm
n/a		ER	670 cfm

J. BASE MODELS AVAILABLE FROM AIRVAC

CONTAINERIZED VERSION 1 & VERSION 2- BASE MODELS Uses either a 1000 gal or 1500 gal collection tank			
Version 1 **using Mink vacuum pumps**		**Version 2** **using Mink vacuum pumps**	
Vacuum Pumps	**Tank size**	**Vacuum Pumps**	**Tank Size**
2-103M	1000 gal	2-165M	1500 gal
2-165M	1000 gal	2-277M	1500 gal
Sewage pumps vary per specific application			

PACVAC VERSION 1 & VERSION 2 - BASE MODELS Uses a 1300 gal collection tank			
MODEL M **using Mink vacuum pumps**		**MODEL R** **using R5 vacuum pumps**	
2 Vacuum Pumps	**3 Vacuum Pumps**	**2 Vacuum Pumps**	**3 Vacuum Pumps**
2-103M	3-103M	2-117R	3-117R
2-165M	3-165M	2-170R	3-170R
Each of these 8 base models are available with either 7.5 hp or 20 hp sewage pumps			

PACVAC VERSION 3 - BASE MODELS Collection tank available in 1500, 2000, 2500 or 3000 gal sizes			
MODEL M **using Mink vacuum pumps**		**MODEL R** **using R5 vacuum pumps**	
2 Vacuum Pumps	**3 Vacuum Pumps**	**2 Vacuum Pumps**	**3 Vacuum Pumps**
2-165M	3-165M	2-170R	3-170R
2-277M	3-277M	2-305R	3-305R
2-353M	3-353M	2-455R	3-455R
Each of these 12 base models are available with either 10 or 20 hp sewage pumps.			

PRELIMINARY SELECTION - when Mink vacuum pumps are used

Pk Q (gpm)	# Conn *	TANK SIZING By Formula Vo (gal)	By Formula Vct (gal)	Actual Vct (gal)	STATION MODEL (based on Pk Q & A/L = 8)
25	39	46	500	1000	**Containerized Ver 1**
50	78	90	700	1000	2-103M
65	100	130	800	1000	2-165M
75	118	137	800	1500	
100	157	186	1000	1500	**Containerized Ver 2**
125	196	233	1100	1500	2-165M
150	235	276	1200	1500	2-277M
175	274	323	1400	1500	
200	313	367	1500	1500	

75	118	137	800	1300	**PacVac Ver 1 or Ver 2**
100	157	186	1000	1300	2-103M 3-103M
125	196	233	1100	1300	2-165M 3-165M
150	235	276	1200	1300	
175	274	323	1400	1500	**PacVac Ver 3**
200	313	367	1500	1500	
225	353	413	1600	2000	2-165M 3-165M
250	392	457	1800	2000	2-277M 3-277M
275	431	509	1900	2000	2-353M 3-353M
300	470	553	2100	2500	
325	509	599	2200	2500	**Airvac Custom skids**
350	549	643	2200	2500	**also available**
400	627	733	2600	3000	**Airvac Custom skid**
450	705	829	2900	3000	2DM-30 or 3CM-30
500	784	919	3200	4500	
550	862	1009	3400	4500	
600	940	1100	3700	4500	**Airvac Custom skid**
650	1019	1195	4000	4500	3DM-45
700	1097	1286	4300	4500	
750	1176	1376	4500	4500	
800	1254	1472	4800	6000	
850	1332	1562	5100	6000	
900	1411	1652	5400	6000	**Airvac Custom skid**
950	1489	1743	5600	6000	4DM-60
1000	1567	1838	5900	6000	

* *assumes standard Airvac peak flow rate of 0.64 gpm (75 gpcd, 3.5 per/hse, 3.5 peak)*

PRELIMINARY SELECTION - when R5 vacuum pumps are used

Pk Q (gpm)	# Conn *	TANK SIZING By Formula Vo (gal)	Vct (gal)	Actual Vct (gal)	STATION MODEL (based on Pk Q & A/L = 8)
25	39	46	500	800	**Containerized Ver 1** *Not available w/R5 pumps*
50	78	90	700	800	
65	100	130	800	800	
75	118	137	800	1300	**Containerized Ver 2** *Not available w/R5 pumps*
100	157	186	1000	1300	
125	197	233	1100	1300	
150	235	276	1200	1300	
175	274	323	1400	1500	
200	313	367	1500	1500	

75	118	137	800	1300	**PacVac Ver 1 or Ver 2**
100	157	186	1000	1300	2-117R 3-117R
125	197	233	1100	1300	2-170R 3-170R
150	235	276	1200	1300	
175	274	323	1400	1500	**PacVac Ver 3**
200	313	367	1500	1500	
225	353	413	1600	2000	2-170R 3-170R
250	392	457	1800	2000	2-305R 3-305R
275	431	509	1900	2000	2-455R 3-455R
300	470	553	2100	2500	
325	509	599	2200	2500	**Airvac custom skids**
350	549	643	2300	2500	**Also available**
400	627	733	2600	3000	**Airvac Custom skid**
450	705	829	2900	3000	2DR-30 or 3CR-30
500	784	919	3200	4500	
550	862	1009	3400	4500	
600	940	1100	3700	4500	**Airvac Custom skid**
650	1019	1195	4000	4500	3DR-45
700	1097	1286	4300	4500	
750	1176	1376	4500	4500	
800	1254	1472	4800	6000	
850	1332	1562	5100	6000	
900	1411	1652	5400	6000	**Airvac Custom skid**
950	1489	1743	5600	6000	4DR-60
1000	1567	1838	5900	6000	

* *assumes standard Airvac peak flow rate of 0.64 gpm (75 gpcd, 3.5 per/hse, 3.5 peak)*

ENGINEERED CUSTOM VACUUM STATIONS (most common skids highlighted in **bold**)						
	WITH MINK VACUUM PUMPS			**WITH R5 VACUUM PUMPS**		
Tank size (gal)	**2 vacuum pumps**	**3 vacuum pump**	**4 vacuum pumps**	**2 vacuum pumps**	**3 vacuum pumps**	**4 vacuum pumps**
1000	2BM-10			2BR-10		
1500	**2BM-15** 2CM-15	3BM-15		**2BR-15** 2CR-15	3BR-15 3CR-15	
2000	2CM-20 2DM-20	3BM-20		2BR-20 **2CR-20**	**3BR-20** 3CR-20	
2500	**2DM-25**	3BM-25 3CM-25		2B5-25 2CR-25 **2DR-25**	3B5-25 3CR-25	
3000		**3CM-30**		2CR-30 **2DR-30**	**3CR-30**	
3500		3CM-35		2CR-35	3CR-35	
4000		3DM-40		2CR-40	3CR-40	
4500		**3DM-45**		2DR-45	**3DR-45**	
5000			4DM-50	2DR-50	3DR-50	
5500			4DM-55	2-DR-55	3DR-55	
6000			**4DM-60**		3DR-60	**4DR-60**
6500			4DM-65			4DR-65
7000						4DR-70

K. STANDARD AND OPTIONAL EQUIPMENT

Container & PacVac vacuum stations – prices are fixed by model number
The Container and PacVac stations are supplied as a standard item with no optional equipment other than what is described below and on the following pages.

Optional equipment can be requested on the Container or PacVac stations; however optional equipment makes these stations Engineered-custom stations and results in higher prices associated with the optional equipment

Container V1 & V2: Version 1 uses a 1000-gal. tank and either 103 cfm or 165 cfm vacuum pumps while Version 2 uses a 1500-gal. tank and either 165 cfm or 277 cfm vacuum pumps.

PacVac Ver 1 & 2: All models have identical standard features and a 1300-gal. tank. A limited number of component combinations are available including the number of vacuum pumps (2 or 3), the type of vacuum pumps (Mink or R5), the capacity of the vacuum pumps (cfm) and the sewage pump horsepower. There are 8 different models of Version 1 & 2, each available with either 7 ½ or 20 hp sewage pumps.

PacVac Ver 3: All models have identical standard features and tanks ranging from 1500 gal. to 3000 gal. A limited number of component combinations are available including the number of vacuum pumps (2 or 3), the type of vacuum pumps (Mink or R5), the capacity of the vacuum pumps (cfm) and the sewage pump horsepower. There are 12 different models of Version 3, each available with either 10 or 20 hp sewage pumps.

Minor modifications
Slight modifications to the standard stations may be made without incurring additional costs. Some examples:

- Skids can be oriented to face either right or left (mirror images)
- The collection tank nozzles will vary according to the number of vacuum mains and their associated diameters.
- Sewage pump capacity and head conditions may result in spacing and configuration changes.

Engineered-Custom vacuum stations – prices vary according to the final design
These vacuum stations can be custom designed to suit the needs of the client.

CHAPTER 4
VACUUM STATION DESIGN

NOTE: Most of the formulas in this chapter apply only when vacuum mains 10-in. and smaller are used. Contact Airvac's Engineering Department for guidance on adjustments to be made when vacuum mains larger than 10-in. are used.

A. STATION SIZING-GENERAL

Nomenclature used in the station design is given below:

Term	Definition
Q_{max}	Station peak flow (gpm)
Q_a	Station average flow (gpm)
Q_{min}	Station minimum flow (gpm)
Q_{dp}	Discharge pump capacity (gpm)
Q_{vp}	Vacuum pump capacity (cfm)
V_o	Collection tank operating volume (gal)
V_{ct}	Collection tank volume (gal)
t	System pump-down time (min)
V_p	Piping system volume (gal)
V_t	Total system volume (gal)
TDH	Total dynamic head (ft)
H_s	Static head (ft)
H_f	Friction head (ft)
H_v	Vacuum head (ft)

The major station components are generally sized as described in Table 4-1. Detailed formulas for each component are shown in this Chapter. A Vacuum Station Calculation Sheet is included in this chapter.

Table 4-1

Vacuum Station Component Sizing

Component	How Sized
Collection Tank	To insure adequate operating volume to prevent excessive sewage pumping cycles and to provide emergency storage volume.
Sewage Pumps	Based on total peak flow to the vacuum station or as necessary to maintain 2 ft/sec scouring velocity within the force-main whichever is greater.
Vacuum Pumps	Based on: 1) peak flow & length of line and 2) the total system piping volume

B COLLECTION TANK SIZING

Materials

Fiberglass, carbon steel, or 316 stainless steel tanks are acceptable with fiberglass being the preferred material. Steel and SS tanks are of a welded construction and fabricated from not less than 5/16-in. thick steel plates. The tanks are designed for a working pressure of 20-in. Hg vacuum and are tested to 26-in. Hg vacuum for 5 min and 24-in. Hg for 4 hours at the tank manufacturer's facilities. All tanks have 150 psi rated flanges. Fiberglass tanks are fabricated to meet the same specifications with tanks located inside a building meeting ASTM 4097 and buried tanks meeting UL 1316.

The tank is furnished with the required number and size of openings, man-ways, and taps, as shown on the engineer's plans. In addition, the tank is supplied complete with sight glass and its associated valves. When steel tanks are used, they are sand-blasted and then coated. The outside is coated with 6 mils of 2-part epoxy and the inside is coated with 16 mils of immersion duty 2-part epoxy.

Stainless steel tanks typically include an exterior clear coat for aesthetic purposes (to resist fingerprints and stains).

Tank Sizing (Engineered Custom stations only)

Collection tanks are sized to insure adequate operating volume to prevent sewage pump short cycles and emergency storage volume. Tanks may also be sized in anticipation of any future growth.

The tanks are sized based on peak flow to the station. To this peak flow quantity, factors are applied to establish the operation volume for sewage pump cycling. Using these criteria, the sewage pumps will not operate more than 4 times per hour at minimum flow periods (2 starts per pump), nor start more than 7 times per hour at average flow (3.5 starts per pump). This is represented by the following formulas:

$$Vo = 15Q\min(Qdp - Q\min) \div Qdp$$

$$Vct = 3Vo + 400$$

Where Vo = Operating Volume (gal)
$Q\min$ = Minimum Flow (gpm) = $Q_a/2$
Qdp = Sewage Pump capacity (gpm)
Vct = Collection Tank Size (gal)

A safety factor of 3.0 is applied to the operating volume to allow for emergency storage. An additional 400 gallons is added to this subtotal as a reserve volume within the tank for moisture separation and vacuum pump reserve volume.

Table 4-2 gives the value of V_o for a 15-minute cycle at Q_{min} for different peaking factors. The total volume of the collection tank should be 3 times the operating volume ($V_t = 3 \times V_o$) with a minimum recommended size of 1,000 gal.

Table 4-2

Values of V_o for a 15-Minute Cycle at Q_{min} for Different Peaking Factors

Peaking Factor	V_o
3.0	$2.08 \times Q_{max}$
3.5	$1.84 \times Q_{max}$
4.0	$1.64 \times Q_{max}$

After sizing the operating volume, the designer should check to ensure an excessive number of pump starts per hour will not occur. This check should be performed for a sewage flow rate equal to one-half the pump capacity.

When designing the collection tank, the sewage pump suction lines should be placed at the lowest point on the tank and as far away as possible from the main line inlets. The main line inlet elbows inside the tank should be turned at an angle away from the pump suction openings.

The minimum recommended tank size is 1,000 gallons.

Table 4-3

Standard Tank Sizes (gal)

Station type	Nominal size (gal)
Container	1,000 & 1,500
PacVac 1 & 2	1,300
PacVac 3	1,500, 2,000, 2,500 & 3,000
Engineered Custom	1,000 – 7,000 (500 gal increments)

C. SEWAGE PUMP SIZING

Materials

Duplicate pumps, each capable of delivering the design capacity at the specified TDH should be used. These are typically horizontal, non-clog or self-priming centrifugal pumps or dry pit submersible pumps.

Because the pump is drawing from a tank under vacuum, the NPSH calculations are especially critical. A certification from the pump manufacturer that the pumps are suitable for use in a vacuum sewerage installation is strongly recommended.

Each pump should be equipped with an enclosed, non-clog type, two-port, gray iron impeller that is statically and dynamically balanced and capable of passing a 3-in sphere. The impeller should be fastened to a stress-proof steel shaft by a stainless-steel lock screw or locknut. Pumps should have an inspection opening in the discharge casing.

The sewage pumps are the most susceptible component to submergence, so it would be wise to consider dry-pit submersible pumps when protection from 100-year flood levels is required. These pumps may operate in a dry pit under normal conditions and if necessary continue to operate while submerged. The obvious disadvantage is a motor coupled to the pump casing that is sealed making maintenance more difficult. The piping arrangement used with submersible pumps tends to result in slightly lower $NPSH_a$ than their non-submersible counterparts, so some special arrangements may be necessary to satisfy this criterion as well.

Pump capacity

To size the discharge pumps, use the following formula:

$$Q_{dp} = Q_{max} = Q_a \times \text{Peak Factor}$$

Typical peak factors range from 3.0 to 4.0 (see Chapter 2).

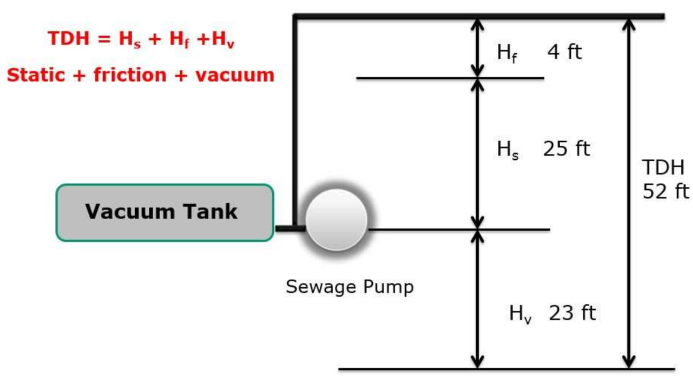
The final selected pump capacity should be as calculated above (Q_{dp}) or as necessary to maintain 2 ft/sec scouring velocity within the force-main, whichever is greater.

TDH Calculations

The Total Dynamic Head (TDH) is calculated using the following formula:

$$TDH = H_s + H_f + H_v$$

TDH is calculated using standard procedures for pumps with the exception that the head attributed to overcoming the vacuum in the collection tank (H_v) must also be considered. This value is usually 23 ft, which is roughly equivalent to 20-in. Hg, which is the typical upper operating value. An example follows.



Since H_v will vary depending on the tank vacuum level, (16-20-in Hg, with possible operation at much lower and higher levels during problem periods) it is prudent to avoid a pump with a flat capacity/head curve. In addition, where possible, horizontal sewage pumps should be used, as they have less suction losses compared to vertical pumps. To reduce suction line friction losses, the pump suction line should be 2 inches larger than the discharge line.

NPSH Calculations

To calculate $NPSH_a$, use the following formulas. Definition of terms and typical values are given in Table 4-4 on the following page.

$$NPSH_a = h_{avt} + h_s - h_f - h_{vpa}$$

$$\text{where} \quad h_{avt} = h_a - V_{max}$$

$NPSH_a$ and TDH should be calculated for both the high and low vacuum operating levels and compared to the $NPSH_r$ at the corresponding point on the head/capacity curve. NPSH characteristics differ from manufacturer to manufacturer, with some better suited for use in a vacuum system than others. Depending on the actual pump selected and where it will operate on the pump curve, the designer should include some margin between $NPSH_a$ and $NPSH_r$. This is especially important for pumps that will operate away from the Best Efficiency Point (BEP) of the pump curve.

Historically, NPSH has proven to be the most critical factor during the pump selection process; however, several other factors, such as efficiency, spherical solid size and cost must be considered as well.

Table 4-4

Discharge Pump NPSH Calculation/ Nomenclature

Term	Definition	Typical Value
$NPSH_a$	Net positive suction head available, ft	-
$NPSH_r$	Net positive suction head required by the pump selected, ft	-
h_a	Head available due to atmospheric pressure, ft	33.9 @ sea level 33.2 @ 500 ft 32.8 @ 1,000 ft 29.4 @ 4,000 ft
h_{avt}	Head available due to atmospheric pressure at liquid level less vacuum in collection tank, ft	-
V_{max}	Maximum collection tank vacuum, ft	18.1 @ 16-inHg 22.6 @ 20-inHg
h_s	Depth of wastewater above pump centerline, ft	1.0 (min)
h_{vpa}	Absolute vapor pressure of wastewater at its pumping temperature, ft	0.8
h_f	Friction loss in suction pipes, ft	1.0

Figure 4-1 is a diagram for calculation of $NPSH_a$ in a vacuum system.

Sewage pump testing by the pump manufacturer

While not normally recommended by Airvac, the design engineer may require that the sewage pumps be hydrostatically tested at the pump manufacturer's plant prior to shipment to Airvac. The pressure rating of the pump unit shall be within the limits set forth by the Hydraulic Institute - Level "A". Unless otherwise agreed, this is to be at a tolerance of +8% total head with no negative tolerance.

At least one of the two pumps are to be operationally tested to the duty point specified and certified copies of both the curve established and the pump curve points should be published prior to pump shipment to Airvac.

If required by the design engineer due to concerns over $NSPH_r$, at least one of the two pumps should be tested for Net Positive Suction Head Required ($NPSH_r$) and the results shall clearly indicate final $NPSH_r$ for the pump tested. Certified results should be published prior to pump shipment to Airvac.

Sewage pump testing by Airvac
As part of the skid fabrication process, Airvac will be operate the sewage pumps at as close to field conditions as possible prior to shipment. A factory start-up report with the test results will be incorporated into the O&M Manual.

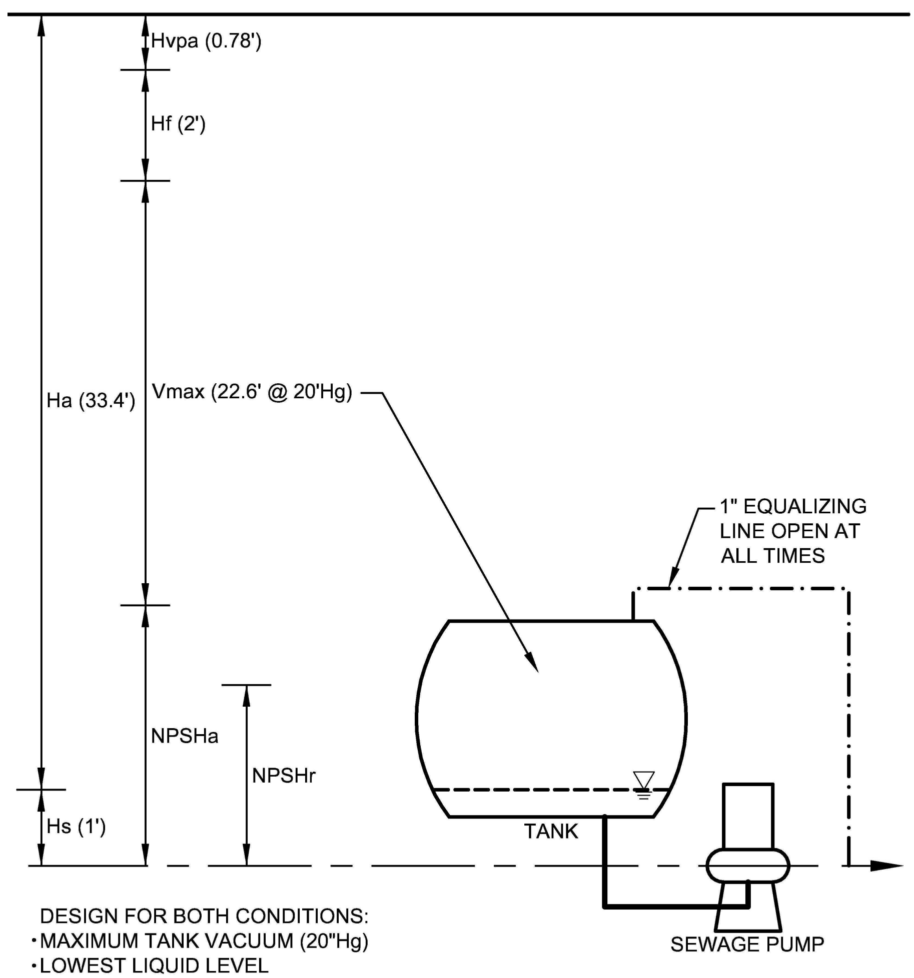


FIGURE 4-1: NPSHa CALCULATION WITH TYPICAL VALUES

D. VACUUM PUMP SIZING

Airvac recommends a rotary claw style vacuum pump which are efficient (air delivered versus electrical energy usage) in the operating range of 16-20-in. Hg. Table 4.5 shows the available vacuum pump models used by Airvac.

To reduce back-pressure on the vacuum pumps, it is recommended that each vacuum pump have its own exhaust line. If the exhaust lines are to be manifolded, check valves are required on each exhaust line.

Mink MM Series (Aqua) Vacuum Pumps - Recommended
The Busch Mink vacuum pump has replaced the R5 series as Airvac's standard. While slightly more expensive than the R5, the additional cost will easily be offset by the Mink pump being more energy efficient and requiring less maintenance. Mink vacuum pumps operate contact-free; neither oil nor water are required during the compression process. The Mink pumps must be of the "Aqua" version in which a special corrosion protection coating is used.

The Busch MM series positive displacement vacuum pumps feature a compact rotary claw design that is air-cooled, dry-running and non-contacting which results in a pump that offers extremely high reliability and a long service life.

Inside the pump housing, two claw-shaped rotors take in air as they rotate in opposite directions. The air is compressed by the rotors, then discharged through a silencer to atmosphere. The non-return valve incorporated into the inlet flange prevents air from back flowing into the vacuum chamber when the pump is turned off. These vacuum pumps are directly driven by a flanged motor, and the two rotors are synchronized by gears.

The rotary claw operation principle of Mink claw vacuum pumps reduces their energy consumption considerably in comparison with conventional vacuum pumps, so energy costs are reduced. Compared to conventional vacuum pumps, Mink claw vacuum pumps can save up to 60% on energy and operating costs. Due to their near maintenance-free operation, a decrease in operating costs adds to the savings.

R5 Series Vacuum Pumps - Optional
Robustness and reliability of operation are features of the R5 rotary vane vacuum pumps which come standard with heavy-duty carbon fiber composite vanes. The highly efficient exhaust filters for R5 pumps provide optimum oil separation and the standard oil separator ensures clean and oil-free exhaust. The pump is driven by a directly flange-mounted standard electric motor. Maintenance can easily be carried out by the operator which includes regular maintenance checks and oil and filter changes.

Table 4-5

Busch Vacuum Pump - Base models*

Where used	Mink Aqua pumps Model #	cfm	hp	R5 pumps Model #	cfm	hp
Container Ver 1	MM1142BV	103 cfm	5.0 hp	*Not available in Containerized stations*		
	MM1252AV	165 cfm	7.5 hp			
Container Ver 2	MM1252AV	165 cfm	7.5 hp			
	MM1402AV	277 cfm	15 hp			
PacVac - Ver 1 & 2	MM1142BV	103 cfm	5.0 hp	RA 0165D	117 cfm	7.5 hp
	MM1252AV	165 cfm	7.5 hp	RA 0255D	170 cfm	10 hp
PacVac - Ver 3 & Engineered Custom	MM1252AV	165 cfm	7.5 hp	RA 0255D	170 cfm	10 hp
	MM1402AV	277 cfm	15 hp	RA 0400C	305 cfm	15 hp
	MM1502AV	353 cfm	15 hp	RA 0630C	455 cfm	25 hp
Engineered Custom only	*Not available at the time this manual was published*			RA 1000B	670 cfm	40 hp

** Shown are the base model Busch pumps typically used by Airvac. Other pump models are available (for example: Model 1322AV, 212 cfm, 9 hp) as an option.*

Vacuum Pump Sizing

Vacuum pump sizing requires two separate calculations. The first calculation involves peak flow and the longest line length. The second calculation involves total pipe volume. Both criteria should be checked, and the larger value used to select the vacuum pumps.

Step 1 – Vacuum Pump Size Based on Flow and Line Length

To calculate the required capacity of the vacuum pumps (Q_{vp}) based on peak flow and the longest line length, the following formula is used:

$$Q_{vp} = A \times Q_{max}/7.5 \text{ gal/ft}^3$$

where Q_{max} is the expected peak flow (gpm) and "A" varies empirically with mainline length as shown in Table 4-6.

Table 4-6

"A" Factor for Use in Vacuum Pump Sizing

Longest Line Length (ft)	A
0 - 5,000	6
5,001 - 7,000	7
7,001 -10,000	8
10,001 -12,000	9
>12,000	11

Step 2 – Vacuum Pump Size Based on Pipe Volume

To calculate the required capacity of the vacuum pumps (Q_{vp}) based on total pipe volume, the following formula is used:

$$Q_{vp} = \frac{(P_f)\ \text{cfm-min}}{\text{gal}} \times \frac{(2/3\ V_p + (V_{ct} - Vo))\ \text{gal}}{3\ \text{min}}$$

where:

Q_{vp} = Vacuum pump capacity required (cfm)
P_f = Pressure factor (cfm-min/gal)
V_p = Volume of collection system piping (gal)
V_{ct} = Volume of collection tank (gal)
V_o = Operating volume of collection tank (gal)

The pressure factor (P_f) is based on an operating range of 16 to 20-in. Hg and the altitude (elevation) of the vacuum station site.

Table 4-7

Pressure Factor (P_f)
@ operating vacuum range of 16-in. Hg to 20-in. Hg

Elevation	P_f	Elevation	P_f	Elevation	P_f
0 - 400	.045	2001- 2500	.058	6501 - 7000	.111
401 - 500	.047	2501- 3000	.061	7001 - 7500	.123
501 - 600	.048	3001- 3500	.066	7501 - 8000	.139
601 - 700	.048	3501- 4000	.070	8001 - 8500	.157
701 - 800	.048	4001- 4500	.075	8501 - 9000	.182
801 - 900	.049	4501- 5000	.080	9001 - 9500	.218
901 -1000	.050	5001- 5500	.086	9501-10000	.280
1001 -1500	.053	5501- 6000	.093		
1501 -2000	.055	6001- 6500	.101		

Step 3 – Select pump
Using the larger of the two values returned in Step 1 and Step 2, select a vacuum pump from Table 4-5. The quantity and size of vacuum pump must provide 100 percent of the required airflow provided by the cumulative total capacity of all pumps less 1, with the additional pump functioning as a standby with the same capacity as the others.

For example, if the calculations show that a total of 850 cfm is required, 3-455 cfm pumps are required (3-1 = 2 x 455 cfm = 910 cfm which is > 850 cfm).

Step 4 – Check System Pump-down Time ("t")
System pump-down time is the time it takes the total number of vacuum pumps less 1 to evacuate (pump-down) the collection piping network from a starting level of 16-in. Hg to a final level of 20-in. Hg.

$$t = \frac{(P_f \text{ cfm-min})}{\text{gal}} \times \frac{(2/3\ V_p + (V_{ct} - V_o))\text{ gal}}{(\text{Total \# VP's} - 1) \times Q_{vp}\text{ cfm}}$$

where:

t	=	System pump-down time (min)
P_f	=	Pressure factor (cfm-min/gal)
V_p	=	Volume of collection system piping (gal)
V_{ct}	=	Volume of collection tank (gal)
V_o	=	Operating volume of collection tank (gal)
Q_{vp}	=	Selected Vacuum pump capacity (cfm)

In no case should "t" be greater than 3 minutes or less than 1 minute. If "t" is greater than 3 minutes, the capacity of the vacuum pumps should be increased, or additional pumps added. If "t" is less than 1 minute, a lower capacity vacuum pump should be used.

Special conditions
Please contact Airvac if the design includes an EAAC (see discussion in Chapter 5) or system operation is expected at levels other than 16-20-in. Hg, as these may require an additional and/or a larger vacuum pump. Also, if higher operating vacuum ranges are anticipated, double-check the NPSH calculations of the sewage pumps as $NPSH_a$ will be affected by the higher levels.

PROJECT	________________	PROJECT NUMBER	________________
STATION NUMBER	________________	DATE	________________

FLOW CALCULATIONS

# connections		______ Present	x	______ growth rate		= ______ Future		**(a)**
Residential Flow rate (gpcd)	=	______	**(b)**		Per/hse	= ______		**(c)**
Ave daily flow (residential)		______ **(a)**	x	______ **(b)**	x	______ **(c)**	= ______	gpd	**(d)**
Peak factor							______		**(e)**
Peak flow (Residential)	(d) x (e) / 1,440	=		______ 1,440	x	______ **(e)**	= ______	gpm	**(f)**
Other Peak flow (Comm)							______	gpm	**(g)**
Total Peak Flow	(f) + (g)	=		______ **(f)**	+	______ **(g)**	= ______	gpm	**Qmax**
Average Flow		=		Qmax / (e)	=	______	= ______	gpm	**Qa**
Minimum Flow		=		Qa / 2	=	______ / 2	= ______	gpm	**Qmin**

SEWAGE PUMP CALC's

Pump Capacity		=		Qmax			= ______	gpm	**Qdp**
TDH @ 16" Hg =		18.1 Vacuum	**+**	______ Static	+	______ Friction	= ______	ft	
TDH @ 20" Hg =		22.6 Vacuum	**+**	______ Static	+	______ Friction	= ______	ft	
NPSHa @ 16" Hg =	______ (havt)	+ ______ (hs)	-	______ (hf)	-	______ (hvpa)	= ______	ft	
NPSHa @ 20" Hg =	______ (havt)	+ ______ (hs)	-	______ (hf)	-	______ (hvpa)	= ______	ft	
	NOTE:	Havt	=	[ha	-	Vmax]			

COLLECTION TANK SIZING

Operating Volume	=	15 Qmin (Qdp – Qmin) / Qdp	=	15 x x (-)	= ______	gal	**Vo**
Tank Volume required	=	[Vo x 3] + 400	=	(x 3) + 400	= ______	gal	
Selected tank Volume				(round up to nearest 500 gal)	______	gal	**Vct**

FIGURE 4-2: STATION CALCULATIONS

PROJECT	______________	PROJECT NUMBER	______
STATION NUMBER	______________	DATE	______

VACUUM PUMP CALCULATIONS

A. Step 1 – Size Based on Peak Flow and Line Length

Longest Line Length			"A"
0	-	5,000	6
5,001	-	7,000	7
7,001	-	10,000	8
10,001	-	12.000	9
12,001	-	15,000	11

Mink Pumps	R5 pumps
165 cfm	170 cfm
277 cfm	305 cfm
353 cfm	455 cfm
	670 cfm

Longest Line = ______ lf

Vacuum Pump capacity required = Qvp = $\frac{\text{A x Qmax}}{\text{7.5 gal/ft3}}$ = $\frac{(\quad x \quad)}{7.5 \text{ gal/ft}^3}$

Qvp = ______cfm

B. Step 2 – Size Based on Pipe Volume

LINE LENGTHS & PIPE VOLUME						
Line	3"	4"	6"	8"	10"	12"
A						
B						
C						
D						
Total Pipe footage	lf	lf	lf	lf	lf	lf
x	0.0547 ft^3/lf	0.0904 ft^3/lf	0.1959 ft^3/lf	0.3321 ft^3/lf	0.5095 ft^3/lf	0.7260 ft^3/lf
Pipe Volume =	ft^3	ft^3	ft^3	ft^3	ft^3	ft^3

Vp = ______ ft^3 x 7.48 gal/ft^3 = ______ gal

Vacuum Pump capacity required = Qvp = $\frac{\text{Pf (cfm-min) x [2/3 Vp + (Vct-Vo)] gal}}{\text{gal} \quad \text{3 min}}$

(Pf from Table 4-6)

Qvp= $\frac{(\quad) \text{ x [(2/3 x } \quad) + (\quad - \quad)]}{3}$

Qvp = ________ cfm

C. Step 3 & 4 – Select pump size & quantity using the larger of A & B above; check "t"

t = $\frac{\text{Pf (cfm-min) x [2/3 Vp + (Vct-Vo)] gal}}{\text{gal} \quad \text{[\# pumps –1] x Qvp cfm}}$

"t" should be less than 3 min. If over, increase Qvp or add vacuum pumps

t = $\frac{(\quad) \text{ x [(2/3 x } \quad) + (\quad - \quad)]}{(\quad - 1) \text{ x } (\quad)}$

If "t" is under 1 min, increase Vct

t = ________ min

FIGURE 4-2: STATION CALCULATIONS

VACUUM FORMULAS AND CONVERSION FACTOR

Absolute Pressure Based On U.S. Std Atmosphere

ALTITUDE	PRESSURE	
(Feet)	In. Hg.	PSI
0	29.92	14.70
500	29.38	14.43
600	29.28	14.38
700	29.18	14.33
800	29.07	14.28
900	28.97	14.23
1,000	28.86	14.18
1,500	28.33	13.90
2,000	27.82	13.67
2,500	27.31	13.41
3,000	26.81	13.19
3,500	26.32	12.92
4,000	25.84	12.70
4,500	25.36	12.45
5,000	24.89	12.23
5,500	24.43	12.00
6,000	23.98	11.77
6,500	23.53	11.56
7,000	23.09	11.34
7,500	22.65	11.12
8,000	22.22	10.90
8,500	21.80	10.70
9,000	21.38	10.50
9,500	20.98	10.30
10,000	20.58	10.10

Multiply	By	To Obtain
lb./square inch (psi)	2.036	Inches mercury
lb./square inch (psi)	27.684	Inches water
lb./square inch (psi)	5.17	Cm. mercury
lb./square inch (psi)	70.317	Cm. water
lb./square inch (psi)	703.09	Kg/m^2
Inches water	0.0735	In. mercury
Inches water	0.036	Lb./sq. inch
Inches water	2.54	Cm. water
Inches mercury	0.4912	Lb./sq. inch
Inches mercury	13.60	In. water
Inches mercury	2.54	Cm. mercury
Gal. Water	8.337	Lb.
Gal.	0.1337	Cu. Ft.
Cu. Ft.	7.48	Gal.
Cu. Ft.	0.0283	Cu. Meters
Horsepower	746.	Watts
Kilowatts	1.341	Horsepower
M^3/min.	35.31	Cfm
cfm	1.6992	m^3/hr.

AIRVAC® SYSTEM PUMP DOWN TIME

The following formulas will give pump down time for an empty vacuum system.

SYSTEM PUMP DOWN TIME

$$t - \frac{2.3V}{S} \quad \log \frac{P_1}{P_2}$$

t = time in minutes
V = volume of system in cubic feet
S = average pump speed in CFM from P_1 to P_2
P_1 = initial pressure - psia
P_2 = final pressure - psia

The following examples illustrate two (2) typical operating conditions

For pumping 0 to 20” Hg

$$t\,(min) - \left(0.147 \frac{cfm - min}{gal}\right) \frac{Vp + Vct + Vrt}{Qvp}$$

For pumping 16” Hg to 20” Hg

$$t\,(min) - \left(0.045 \frac{cfm - min}{gal}\right) \frac{Vp + Vct + Vrt}{Qvp}$$

DEFINITIONS

FREE AIR (SCFM)
Free Air is air at normal atmospheric pressure. Because the altitude, barometer and temperature vary at different localities and at different times, it follows that this term does not mean air under identical conditions.

DELIVERED AIR (ACFM)
Vacuum Pump: Delivered air is the actual volume of expanded air under the vacuum condition expressed in CFM at the vacuum pump intake.

SCFM
Standard Cubic Feet per Minute.
Delivered, free air at 14.7 PSIA and 70°F

$$\frac{30''}{30'' - V\,(in.Hg)} \times SCFM = ACFM$$

EXPANDED AIR
Expanded Air is air under a partial vacuum or below atmospheric pressure. A true vacuum is a space without any air or gas and represents zero absolute pressure.

ABSOLUTE PRESSURE
Absolute Pressure is the total pressure above true zero. When working below atmospheric pressure it is less than 14.7 pounds per square inch. When working above atmospheric pressure, the absolute pressure is the sum of the atmospheric pressure and the gauge pressure.

ATMOSPHERIC PRESSURE
Atmospheric Pressure at sea level is 14.7 pounds per square inch above zero absolute pressure or 29.93 inches mercury.

E. ELECTRICAL PANEL

Following is a general description of the electrical panel; however, there are many options that can be selected. See Chapter 3 for a discussion on the standard equipment normally associated with an Airvac vacuum station skid as well as the optional equipment that is available.

<u>Motor Control panel</u>
Rather than using a Motor Control Center (MCC), most vacuum stations use a smaller control panel that can be either remote mounted, or attached directly to the equipment skid. These control panels are specifically designed for each station.

The control panel enclosure is to be NEMA Type 12. A main disconnect switch, sized to handle the current draw for all related vacuum station equipment is to be provided.

The panel includes motor starters for each motor. Typically, either IEC or NEMA motor starters are used. To reduce in-rush current and increase life of the pumps, variable frequency drives (VFDs) can be supplied. VFDs can also be used to modulate the speed of the pumps based on demand. PLC control, with relay outputs, executes logic based on proprietary programming.

Discharge pump level control is controlled by a radar level sensing device with a float provided for high level backup. The panel should include pilot lights, hand-off-auto (HOA) switches, elapsed time meters, or an industrial quality operator interface. If the operator interface is selected, trending and data logging can be performed to monitor vacuum system performance. If not, a 7-day chart recorder can be installed in the enclosure. For alarms and monitoring, the control panel can be integrated into any existing SCADA system, or a new SCADA system can supplied by Airvac. A traditional telephone dialer can also be provided if preferred.

In small station designs, the control panel is wired to each motor and control device by Airvac. Larger, more complex designs require the contractor to wire the control panel to the related junction boxes provided on the equipment. Control panels are built and labeled in compliance with UL Standard 508a, but can be constructed in accordance with UL 698a where a classified hazardous location installation is required.

Wiring inside the panel is to be NEMA Class II, Type B. Where Type B wiring is indicated, the terminal blocks should be located in each section of the control panel.

The enclosure should be NEMA Type 12-with-Gasketed Doors. Vertical sections shall be constructed with steel divider side sheet assemblies formed or otherwise fabricated to eliminate open framework between adjacent sections or full-length bolted-on side sheet assemblies at ends of the panel. The panel should be assembled in such a manner that it is not necessary to have rear accessibility to remove any internal devices or components. All future spaces and wire-ways are to be covered by blank doors.

Relay logic vs. PLC

Control panels typically use PLC logic, although some prefer the simplicity of relay-logic and may not want the sophistication of using a PLC. PLC logic allows for more control over the system by changing the ladder logic through a touch screen or laptop computers and a modem. Also, many of the larger municipalities prefer PLC logic as it matches other controls they may have with lift stations and/or their treatment plant.

F. LEVEL CONTROLS

Vacuum level

Vacuum level is sensed by a 4-20ma vacuum transmitter. The vacuum transmitter is mounted inside of the control panel, and is connected to the collection tank with a ¼ -in. pressure line.

Sewage level

Three types of level controls are available: 7-conductance probes, a single capacitance probe and a radar probe. Many older systems used the 7-conductance probes for level controls but in recent years the single capacitance probe, which can monitor all the set points normally associated with level controls, has been the most commonly used.

At the time this manual was published, Airvac was in the process of testing a radar-type probe which has shown promise and may be the probe of choice in the future. When used, sewage level is sensed by a radar level sensing transmitter with a 4-20ma output. A backup float is provided to protect the vacuum pumps if for some reason the level sensor fails.

Consult with Airvac's Engineering Department for updates on whether radar-type probes are an acceptable alternative to either the capacitance or conductance type probes.

Typical set points when 7-conductance probes are used:

1. Ground
2. Sewage pumps off
3. Lead sewage pump on
4. Lag sewage pump on
5. High level alarm
6. High level reset
7. High level lockout: stops all sewage pumps (auto position only) and vacuum pumps (auto and manual positions)

Figure 4-3 gives approximate elevations of these set points in the collection tank relative to the discharge pumps and incoming vacuum mains.

PROBE	NOTE
1	1" ABOVE TANK BOTTOM
2	6" ABOVE DISCHARGE PUMP VOLUTE
3	15" - 24" ABOVE PROBE #2 AS REQUIRED FOR OPERATION VOLUME
4	4" - 6" ABOVE PROBE #3
5	4" ABOVE PROBE #4 (MIN)
6	EVEN WITH OR ABOVE PROBE #5
7	AT BOTTOM OF INLET LINES

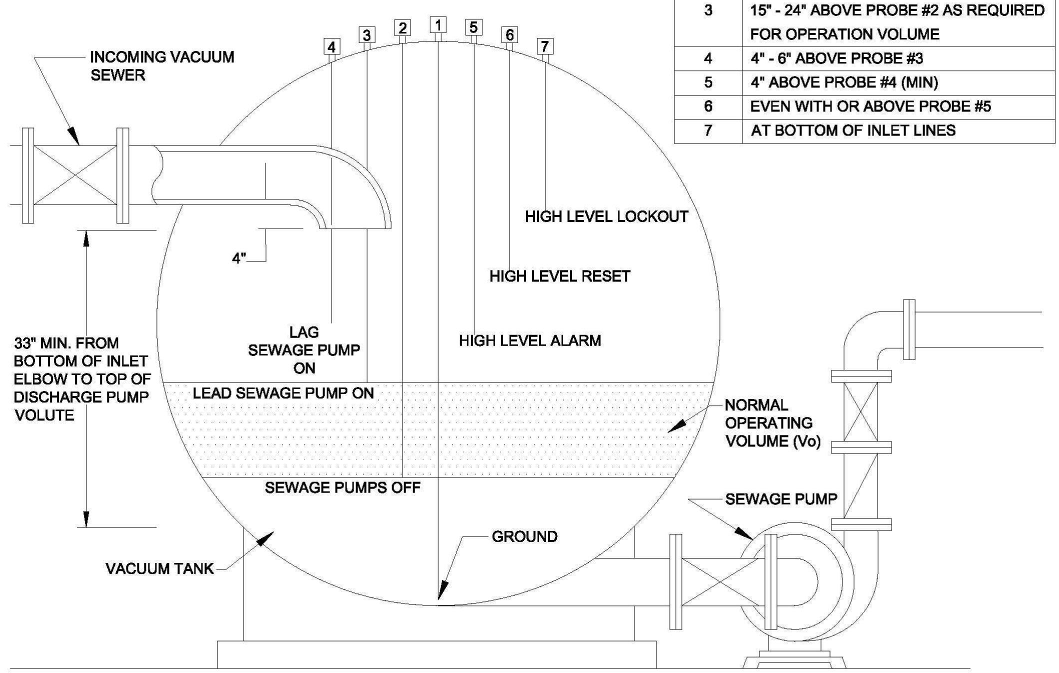


FIGURE 4-3 LEVEL CONTROL PROBE DIAGRAM

G. OTHER STATION COMPONENTS

Equalizing lines
Airvac recommends installing a 1-in. NPT equalizing line on the discharge side of each sewage pump. Clear, flexible PVC tubing is recommended for these so that small air leaks or blockages will be clearly visible to the system operator. Some entities have eliminated equalizing lines by using a ball check valve between the tank and the sewage pump inlet although not all ball check valves will perform satisfactorily, especially those with a short “face to face” dimension. Contact Airvac Engineering for guidance if considering the use of ball check valves.

In either case, the purpose is to equalize the pressure on both sides of the pump. This ensures that the impeller is filled with liquid when the pump starts which allows the sewage pump to start without having to pump against the vacuum in the collection tank.

Vacuum Gauges
On the upstream side of each vacuum sewer isolation valve, a vacuum gauge of not less than 4 ½ inch diameter should be installed. Gauges should be positioned so that they are easily viewed when the isolation valves are operated. Diaphragm seals should not be used with compound gauges.

All vacuum gauges should be specified to have a stainless-steel bourdon tube and socket and to be provided with ½ inch bottom outlets. Stainless-steel ball valves should be used as gauge cocks.

The connection from the incoming main lines to the vacuum gauges should be made using a threaded white nylon nipple and 3/8th inch clear tubing.

Vacuum Recorder
The control panel should contain a graphical digital logger with a touch screen. As an option, a 7-day circular chart recorder, mounted through the face of the enclosure door and connected to a 4-20ma vacuum transducer mounted inside the enclosure, can be used instead. In either case, the recording range is to be 0 to 30-in. Hg vacuum.

Station Piping & valves
Station piping includes all piping within the station, connecting piping to the collection tank, vacuum sewer lines, and force mains. This item includes piping, valves, fittings, pipe supports, fixtures, drains, and other work involved in providing a complete installation.

Wastewater, vacuum, and drain lines 4 inch and larger should be ductile iron, using AWWA/ANSI C110/A21.10 as standard. An exception is the vacuum header pipe which can be Sch 80 PVC. Pipe and fittings in the vacuum station should be flanged with EPDM gaskets. Exposed vacuum lines and other piping smaller than 4-inch can be Sch 80 PVC, 304 Stainless Steel or galvanized.

The vacuum station piping should be adequately supported to prevent sagging and vibration. It also should be installed in a manner to permit expansion, venting, and drainage. For fiberglass tanks, all piping must be supported so that the tank flanges support no weight. Flange bolts should only be tightened to the manufacturer's recommendations. Provisions must be allowed for inaccurate opening alignment.

All shut-off valves fitted within the vacuum station should be flanged, resilient coated plug valves with circular ports.

Check valves fitted to the vacuum piping are to be of the 125-lb. bolted bonnet, rubber flapper, and horizontal swing variety and with Buna-N soft seats. Check valves fitted to the sewage discharge piping are to be supplied with an external lever and weight to ensure positive closing. They also should be fitted with Buna-N soft rubber seats.

Exhaust piping from the vacuum pumps should not be manifolded as this may result in condensation buildup and additional back pressure on the vacuum pumps which adversely affects their performance. If the designer chooses to manifold the exhaust lines, check valves should be used on each exhaust line.

Station Sump Valve

The basement of the vacuum station should be provided with a 15-in. x 15-in. x 12-in. deep sump to collect wash-down water. A 2-inch Airvac vacuum valve that is connected by piping to the collection tank empties this sump. A 2-inch check valve and polypropylene ball valve should be fitted between the sump valve and the collection tank.

Fault Monitoring System

Fault monitoring is typically done through a SCADA system and is used to alert the operator of system abnormalities and station emergencies.

A lower budget alternative is a self-contained, voice communication-type automatic telephone dialing alarm system capable of automatically monitoring up to four independent alarm conditions. Dialers using either a land line or a cellular connection are acceptable. If phones lines are used, provisions must be made to isolate the system from interference. The monitoring system should be provided with continuously charged batteries for 24 hours standby operation in the event of a power outage.

H. NOISE, HEAT, and ODOR CONSIDERATIONS

While Airvac can provide some general guidance regarding noise, heat, ventilation, and odor control based on our experience on past projects, Airvac is not an expert in any of these fields. *It is the design engineer's responsibility to design the station in accordance with any local or national code/ordinance and to ensure that noise, heat, ventilation, and odor concerns are properly addressed.*

Noise

Noise generated by a vacuum station is typically associated with the vacuum pumps and the standby generator. Information regarding noise decibel levels created by these station components as well as others should be obtained from the equipment manufacturer.

Heat & ventilation

Heat within the vacuum station is generated primarily from the sewage pump motors and the vacuum pumps. This heat is added to ambient conditions and can add up during hottest periods of the day. To prevent heat buildup and to ensure that excessive heat does not damage equipment, electrical controls or result in shortened equipment life, vacuum stations should be designed with adequate air exchange rates provided through ventilation equipment. Maximum recommended operating temperature for station equipment is 104 degrees F.

Odor

Because the collection tank is sealed, odors at a vacuum station are only possible through the vacuum pump exhaust lines when the vacuum pumps are running. By connecting the exhaust lines to an odor control system, odors can virtually be eliminated. The use of a bio-mass compost bed has been found to be the most effective method of dealing with potential odors at a vacuum station. Other methods employed include chemical neutralization, activated carbon absorption systems and absorption by manufactured bio-mass filters.

I. STANDBY GENERATOR

A generator is used to provide standby power for duty discharge and vacuum pump operation. It can be located either inside or outside the vacuum station. A portable generator unit is sometimes used which may provide power for several vacuum stations. This is more common where power interruptions are rare and allows the unit to be taken in for service when required.

Sizing of the generator is the design engineer's responsibility. In some cases, particularly with Compact and PacVac stations, Airvac may provide the generator as part of its vacuum station skid supply.

J. DO'S AND DON'TS

Table 4-8

Do's and Don'ts: Vacuum Station Design

DON'T DO THIS:	DO THIS:
Forget to include vacuum head in the TDH calculations	Include an additional 23 ft of vacuum head to overcome tank vacuum
Size vacuum pumps solely on peak flow and Air/Liquid ratio	Perform secondary check based on pipe volume ("t" calculation)
Manifold exhaust lines from vacuum pumps	Use individual exhaust lines for each vacuum pump OR use check valves on each exhaust line if they are manifolded
Undersize the collection tank	Use a minimum collection size of 1000 gal Always include 400-gallon reserve
Select a discharge pump with poor NPSH characteristics	Make sure $NPSH_a$ exceeds $NPSH_r$ with some margin depending on the actual pump selected
Use vertical discharge pumps without first consulting Airvac	Use horizontal discharge pumps when possible
Use odd tank sizes and station configurations that require custom design	Use standard Airvac skid arrangements as shown in Chapter 3
Forget to consider heat gain inside the vacuum station	Provide adequate air exchange rates
Apply component sizing formulas in this chapter when vacuum mains larger than 10" are used	Contact Airvac's Engineering Department for guidance on adjustments to be made

CHAPTER 5
VACUUM MAIN DESIGN

A. CONSTRUCTION STANDARDS

Pipe materials
The vacuum piping network connects the individual valve pits to the collection tank at the vacuum station. Typical sizes include 4-in., 6-in., 8-in. and 10-in. pipe. Occasionally 12-in. pipe is required although this is not common.

PVC thermoplastic pipe is normally used for vacuum sewers. SDR 21 PVC pipe is recommended. In some European installations, HDPE, MDPE and ABS have been successfully used. DCIP has also been used, assuming the joints have been tested and found suitable for vacuum service.

To reduce expansion and contraction induced stresses, flexible elastomeric joint ("rubber ring" joint) pipe is recommended. Where rubber ring joint pipe is used, a certificate is to be provided by the manufacturer stating that the pipe has been tested at 22-in. Hg vacuum in accordance with ASTM D-3139 and is guaranteed for use under vacuum conditions. Airvac recommends a double-lipped “Rieber style” gasket be used.

If solvent-welded joint pipe such as Schedule 40 is used, the pipe manufacturer’s recommendations for installation regarding temperature considerations should be followed. The Uni-Bell Handbook of PVC Pipe provides guidance as to proper practices.

Fittings
PVC pressure rated fittings are needed for directional changes, branch to main connections, and service lateral to branch or main connections. Tee fittings and 90-degree bends are not to be used for vacuum service.

Several forms of pressure rated fittings are available including solvent weld, assembled, fabricated, and molded. For all pipe sizes, the engineer must ensure that suitable fittings are available to suit the requirements of the vacuum system.

<u>Bends (ells)</u>
Ell's are to be molded from one piece of pipe or assembled from molded Schedule 40 fittings with Spigot x Gasket Adapters.

<u>Molded solvent weld fittings</u>
Solvent weld fittings for wyes are PVC Schedule 40 per ASTM D2466 from a PVC compound having a cell classification of 12454 conforming to ASTM D-1784.

<u>Molded gasketed joint VacTuf fittings (with Harco VacSeal gasket)</u>
Pressure rated molded fittings with a gasket suitable for vacuum use are available from Harco. Harco VacTuf fittings with a special joint (Harco VacSeal Joint), are IPS diameter PVC pipe and injection molded from dark gray PVC in one piece. Transition gaskets are not permitted. PVC compound is cell classification 12454 per ASTM D1784 and the gasket material is EPDM or SBR per ASTM F477. Fittings are pressure rated 200 psi by the method of AWWA C907. Gasket joints are 200 psi rated per ASTM D3139 and feature a full circumference vacuum shutoff ridge in each gasket groove (Harco VacSeal Joint). The joints comply with all vacuum requirements of ASTM D3139. Fittings meet an in-plane flattening test of 100% deflection without fracture.

These wye fittings are only available in certain sizes (3-in. thru 8-in. only).

Note: *Compared to other fittings, the VacTuf fitting provides an additional benefit of being break resistant. Although very rare, there have been reports of broken 45-degree fittings caused by a rock or similar object travelling through the vacuum main at high velocities. This almost always is the result of construction debris left behind by the homeowner's plumber when installing the house gravity lateral to the valve pit. This is more likely in systems with very high Air to Liquid ratios as there is less liquid to cushion any impact from a foreign object. The VacTuf break resistant bend will absorb these impacts without fracturing. Even though breakages are rare, Airvac recommends the use of the VacTuf fitting as they not only provide the additional breakage protection but also eliminate many solvent weld joints.*

<u>Assembled gasketed joint fittings (with Rieber gaskets)</u>
Assembled joint fittings are made from molded Schedule 40 fittings per ASTM D-2466 and Spigot x Gasket Adapters fabricated from SDR21, 200 psi pressure rated pipe per ASTM D2241. Gasketed joints are "Rieber Style" (or approved equal) 200 psi rated complying with ASTM D3139.

<u>Fabricated miter-cut, butt fused gasket joint fittings</u>
Wyes that are fabricated using a miter cut, butt fused joints are not permitted.

Table 5-1

Fittings - Bends

Configuration	Material	ASTM	Gasket	Manufacturers
Molded solvent weld joint	Sch 40 PVC	D2466 D1784 D3139	n/a	Spears Charlotte Pipe
Molded, gasketed joint	Dark gray PVC VacTuf	D1784 D3139	Harco VacSeal	Harco
Assembled gasketed joint	Sch 40 PVC w/spigot adapters (2) *	D2466 D1784 D3139	Rieber	Specified Harco
Fabricated, miter-cut, butt fused gasketed joint	***NOT PERMITTED IN VACUUM SYSTEMS***			

* *Spigot adapters made from SDR 21, 200 psi*

Molded solvent weld joint

Molded gasketed joint
VacTuf

Assembled gasketed joint

Fabricated, miter cut, gasketed joint

Wyes

Pressure-rated wyes are available in several forms including fabricated solvent weld joints, molded gasketed joints, assembled gasketed joints and fabricated gasketed joints.

Note about pressure rating of wyes*: The material that make up the various forms of wyes is either Sch 40 PVC (140 to 220 psi depending on the diameter) or SDR 21 PVC (200 psi in all diameters); however, due to the geometry of a wye, the manufacturers de-rate them. In general, wye fittings made from Sch 40 are de-rated to 100 psi while those made of SDR 21 are de-rated to 130 psi. In addition, an external fiberglass reinforcement typically is also required.*

Fabricated solvent weld fittings

Fabricated solvent weld fittings for wyes are made from PVC Sch 40 per ASTM D2466 from a PVC compound having a cell classification of 12454 conforming to ASTM D-1784.

Molded gasketed joint fittings (with Harco VacSeal gasket)

Harco VacTuf fittings with a special joint (Harco VacSeal Joint), are IPS diameter PVC pipe and injection molded from dark gray PVC in one piece. Transition gaskets are not permitted. PVC compound is cell classification 12454 per ASTM D1784 and the gasket material is EPDM or SBR per ASTM F477. Fittings are pressure rated 200 psi by the method of AWWA C907. Gasket joints are 200 psi rated per ASTM D3139 and feature a full circumference vacuum shutoff ridge in each gasket groove (Harco VacSeal Joint). The joints comply with all vacuum requirements of ASTM D3139. Fittings meet an in-plane flattening test of 100% deflection without fracture.

These wye fittings are only available in certain sizes (4 x 3, 4 x 4 and 6 x 3).

Assembled gasketed joint fittings (with Rieber gaskets)

Assembled joint fittings are made from molded Schedule 40 fittings per ASTM D-2466 and Spigot x Gasket Adapters fabricated from SDR21, 200 psi pressure rated pipe per ASTM D2241. Gasketed joints are “Rieber Style” (or approved equal) 200 psi rated complying with ASTM D3139.

Fabricated gasketed joint fittings (with Rieber gaskets)

Fabricated gasketed joint fittings are IPS diameter fabricated from SDR 21, 200 psi pressure rated PVC pipe per ASTM D2241 and Spigot Adapters fabricated from SDR 21, 200 psi pressure rated pipe per ASTM D241. Gasketed joints are “Rieber Style” (or approved equal) 200 psi rated complying with ASTM D3139.

Table 5-2

Fittings - Wyes

Configuration	Material	ASTM	Gasket	Manufacturers
Fabricated solvent weld joint	Sch 40 PVC	D2466 D1784 D3139	n/a	Spears
Molded gasketed joint (special order)	Dark Gray PVC VacTuf	D1784 D3139	Harco VacSeal	Harco
Assembled gasketed joint	Sch 40 PVC w/spigot adapters (3) *	D2466 D1784 D3139	Rieber	Specified
Fabricated gasketed joint	SDR 21 PVC w/spigot adapter (1) *	D2241 D3139	Rieber	Specified Harco

* *Spigot adapters made from SDR 21, 200 psi*

Fabricated solvent weld joint

Molded gasketed joint

Assembled gasketed joint

Fabricated gasketed joint

Vertical Profile changes (lifts)
Lifts or vertical profile changes are used to maintain shallow trench depths as well as for uphill liquid transport (Figure 5.1). These lifts are made in a saw-tooth fashion using 45-degree ells.

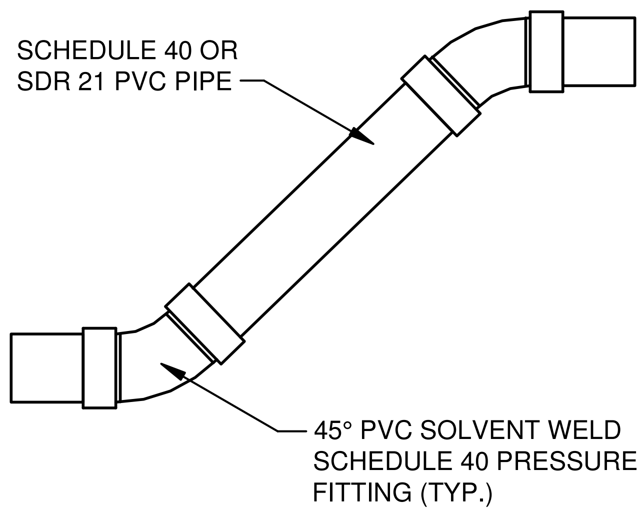


FIGURE 5-1: LIFT DETAIL USING SOLVENT WELD FITTINGS

A single lift consists of two (2) 45-degree fittings connected with a short length of pipe. Airvac recommends that lifts be made in either 1.0 ft. or 1.5 ft. increments depending on pipe size (see Table 5-15).

Horizontal directional changes
Horizontal directional changes can be made with the use of pressure rated fittings as described on pages 5-2 and 5-3. Elbows of 45-degrees or less are permitted, while Tee fittings and 90-degree fittings are not allowed. There is no restriction on the spacing between elbows used for directional changes.

Location tape (optional)
At the engineer's discretion, an inert polyethylene tape having a metallic core should be laid in the sewer trench at a depth defined by the engineer's specifications.

Division Valves (isolation valves)
Airvac recommends a division valve, also referred to as an isolation valve, at the beginning of each branch and on the mainline near these branch connections. Should branch spacing exceed 1,500 feet, Airvac recommends an additional isolation valve for that section. The purpose of these valves is to isolate sections of the vacuum system for trouble shooting purposes and the above listed standards have proven to be sufficient in past years. Airvac recommends resilient-wedge gate valves be used.

Gauge taps
A gauge tap, installed just downstream of the isolation valve, makes it possible for one person to troubleshoot without having to check vacuum at the station. This reduces emergency maintenance expenses, both from a time and manpower standpoint.

Airvac only recommends the use of gauge taps for entities with limited operating resources (ex- only 1 operator) where areas of the collection system are not easily reached by vehicle within a few minutes time. If the system is fairly contained where the farthest reaches of the system are only minutes from the vacuum station and the operating entity has 2 or more operators, trucks, radios, etc., then gauge taps are of little value and are not recommended.

Cleanouts/Access Points
Airvac does not recommend the use of cleanouts or inspection ports on vacuum lines. There are two reasons for this.

First, cleanouts/access points are unnecessary as access to the vacuum main can be gained at any valve pit by removing the valve. A second, and perhaps more important reason, is the potential they pose for vacuum leaks. Early systems that used them experienced as many, if not more, leaks due to cleanouts than were associated with the actual vacuum main itself.

While not required, cleanouts/access points may be used where line size changes occur and at the end of the vacuum main.

Installation Tolerances-Open Cut
Tolerances for open-cut trenching is typically ± 0.05 ft per 100 ft, or 0.05%, for all pipe sizes. With a target slope of 0.20 %, this means the slope could vary from 0.15% to 0.25%. There should be no sags or bellies in the line. Trench water should not be allowed to enter the pipe during construction.

Installation Tolerances –Horizontal Directional Drilling

Tolerances for directional drilling are the same as those required for open trenching. The "minimum 50 ft at 0.20% prior to a lift" rule applies to directional drilling just as it does to open trenching. Making a directional drill at a slope greater than 0.20% and then immediately using a "non-scheduled" lift to make up the difference is not acceptable.

At the time this manual went to print, Airvac still had not endorsed the use of horizontal directional drilling, primarily due to grade control issues. Table 5-3 shows Airvac's requirements for HDD.

Table 5-3

Airvac requirements for
Horizontal Directional Drilling

Item	Airvac Requirement
Slope	Installed pipe must meet Airvac's slope tolerances (± 0.05 ft per 100 ft)
Sags (bellies) & summits	Are not acceptable
Quality control	HDD firm must be able to electronically verify installed slopes at the time of the installation
System integrity	Installed pipe must be capable of passing Airvac's daily & final vacuum tests
Pipe materials	Must mate up to Airvac products and other system components

On non-critical lines, it may be possible to design for slopes greater than 0.20% in areas where directional drilling is desired. This would not be a construction tolerance but rather a design decision that allows for a more attainable slope (say 0.50%).

Incorrect slopes or sag and summits have larger negative affect when a vacuum main is involved rather than when a branch or service line is involved. An incorrect slope on a service line would affect the operation of just that service line, whereas an incorrect slope on a vacuum main would affect not only that main, but all connected branch and service lines as well.

Testing – Daily Test
At the completion of each day's work, all vacuum sewer mains and vacuum service lateral laid that day are to undergo a 2-hour vacuum test. This is accomplished by testing all pipe previously installed along with the pipe installed that day. A vacuum of 22-in. Hg is applied to the pipes and a maximum loss of vacuum of 1% per hour for a 2-hour test period is permissible.

Testing – Final Test
At the end of the construction period, and prior to the installation of the 3-in. Airvac vacuum valve, the complete vacuum sewer system is to be vacuum tested. The testing procedure is the same as the daily test, except the final test is a 4-hour test. Again, the maximum permissible loss is 1% per hour over the four (4) hour test period (approximately 1-in. Hg loss).

B. SYSTEM LAYOUT GUIDELINES

There are four (4) major items to consider when laying out a vacuum system:

Multiple service zones: By locating the vacuum station centrally, it is possible for multiple vacuum mains to enter the station. This allows the service area to effectively be divided into zones. The net result is smaller pipe sizes and less overall vacuum loss.

More importantly, this results in operational flexibility as well as service reliability. With multiple service zones, the system operator can respond to system problems, i.e., low station vacuum, by analyzing the collection system zone by zone to see which zone has the problem. The problem zone can then be isolated from the rest of the system so that normal service is possible in the unaffected zones while the problem is identified and solved.

Minimize pipe sizes: By dividing the service area into zones, the total peak flow to the station is also spread out among the various zones. This makes it possible to minimize the pipe sizes. For example, a total peak flow of 350 gpm in system with only 1 service zone would require a 10-inch vacuum main to the station with progressively smaller pipe toward the system extremities. By spreading this peak flow equally over four vacuum service zones; only 6-in. and 4-in. pipe would be required.

Minimize vacuum loss: Vacuum loss is generally limited to 13 feet. Items that can result in vacuum loss are increased line length and elevation differences, utility conflicts and the relationship of the valve pit location to the vacuum main. The system layout should take these factors into consideration.

Valve pit spacing: Another important consideration is the location of the valve pits along the vacuum main. To the designer, the valve pit is more than just the connection point for the customer; it is an "energy input" location.

Movement of liquid within the vacuum main depends on differential pressure. The differential is created when a vacuum valve opens and allows atmospheric air to enter a vacuum main that is under a negative pressure. The only place this can happen is where a vacuum valve exists. The fewer the energy inputs that exist, the poorer the transport characteristics become. As a result, designers should avoid layouts that result in long stretches of vacuum main with no house connections.

C. LINE SIZING

Based on hydraulic testing, Airvac has established both absolute maximum flows as well as recommended maximum flows for the various main pipe sizes. Table 5-4 shows these recommendations.

Table 5-4

Maximum Flow for Various Pipe Sizes
(Assuming SDR 21 pipe)

Pipe Diameter (in)	Absolute Maximum Flow (gpm)	Recommended Maximum Flow (gpm)
4	55	38
6	152	105
8	305	210
10	544	374
12	858	590

The minimum diameter for a vacuum main is 4 inches. Three (3) inch vacuum lines are only used for the service lateral (pit to main). Only one (1) valve pit may be connected to a 3-in. service lateral.

The values in Table 5-4 should be used for planning purposes or as a starting point for the detailed design. In the latter case, estimated site-specific flow inputs along with the friction tables should be used in the hydraulic calculations.

A correctly sized line will yield a relatively small friction loss. If the next larger pipe size significantly reduces friction loss, the line was originally undersized.

D. LINE LENGTHS

The length of vacuum mains is governed by two factors. These are static lift and friction losses. As discussed later in this chapter, the static loss generally should not exceed 13 ft and friction losses should not exceed 5 ft.

Due to restraints placed upon each design by topography and sewage flows, it is impossible to give a definite maximum line length. In perfectly flat terrain with no unusual subsurface obstacles present, a length of 10,000 ft can typically be achieved. Should there be some elevation difference to overcome, this length could be shorter. On the other hand, with positive elevation toward the vacuum station, this length could be longer. As an example, one operating system has a single main line branch exceeding 16,500 feet in length.

Since most projects have a combination of uphill, downhill, and level sections, Airvac recommends that the 10,000 feet figure be used as a starting point by the designer when doing the preliminary line layout. Any length in excess of this should only be considered if static and friction losses calculated during the final design allow for such additional length.

Guidelines for line lengths and sizes are shown in Table 5-5.

Table 5-5

Maximum Line Length for Various Pipe Sizes

Pipe Diameter (in)	Where used	Maximum recommended length (ft)
3	Service lateral	300
4	Branch Line/end of main line	2,000 *
6, 8,10 & 12	Main Lines	Limited by static & friction losses

* *Consider upsizing to 6-in. if any of the following conditions exist: 1) future expansion possibility on a 4-in. branch, 2) when friction and/or static losses on a given flow path that includes a 4-in. branch begin to approach the design limits shown in Table 5.16, Group A.*

Airvac engineers will be pleased to advise and assist clients with the design of the vacuum mains once topography and flow rates are available.

E. VACUUM MAIN DESIGN PARAMETERS

Vacuum sewer design rules have been developed largely as a result of studying operating systems. Important design parameters are shown in Tables 5-6.

Table 5-6

Vacuum Main Design Parameters

Minimum distance between lifts, ft – scenario 1	125
Minimum distance between lifts, ft – scenario 2	20
Minimum distance of 0.20% slope prior to a lift or series of lifts, ft	50
Minimum distance between top of lift and any service lateral, ft	6
Minimum slope	0.20%
Maximum # of lifts in a series (see page 4-32)	5

Scenario 1 – use 125 ft (min) spacing between lifts

Fig 5-2a shows a situation where a low spot or a utility conflict has caused the vacuum main to dip down and back up again. In this case, Airvac recommends that the lift spacing be spread out to at least 125 ft to minimize the possibility of waterlogging.

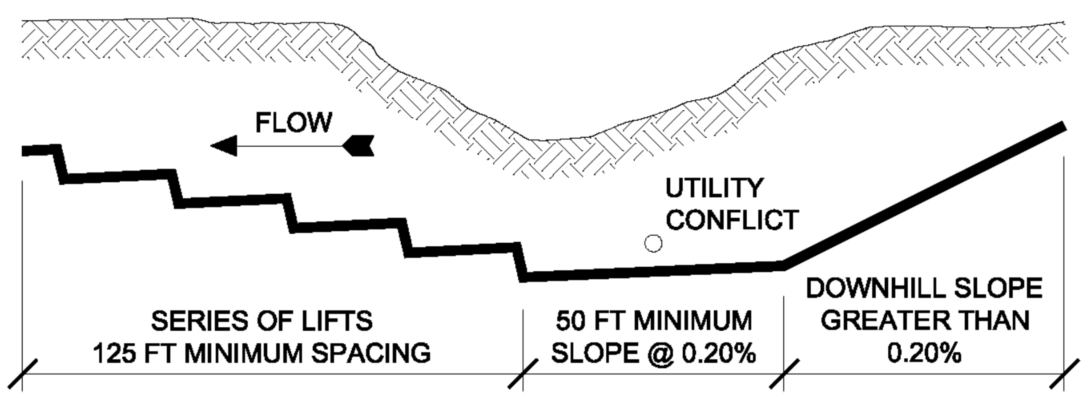


FIGURE 5-2a: SERIES OF LIFTS – Scenario 1

Scenario 2 – Use 20 ft. (min) spacing between lifts

Fig 5-2b shows a situation where the ground level is flat but then goes uphill. In this case, the 20-ft. minimum spacing between lifts is acceptable.

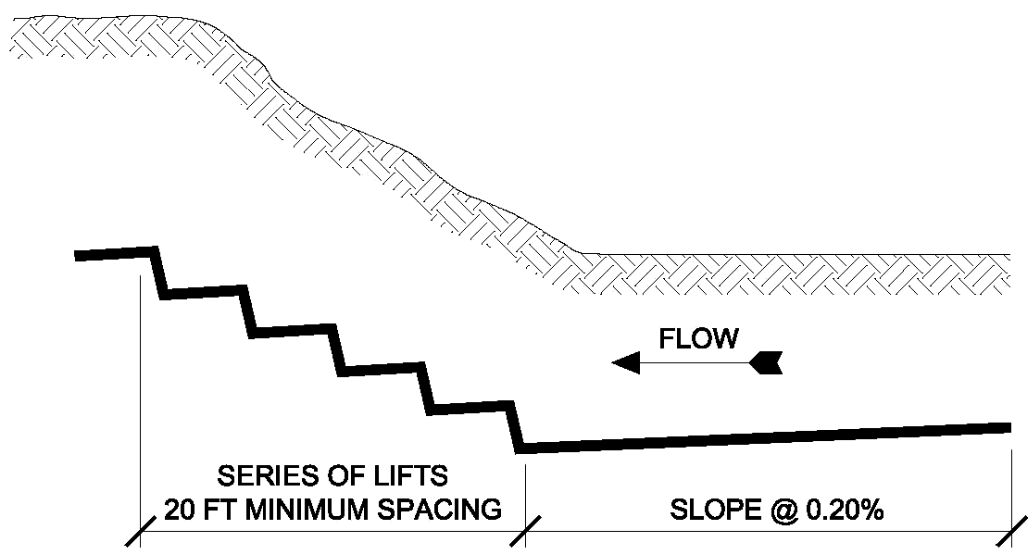


FIGURE 5-2b: SERIES OF LIFTS – Scenario 2

Slope on Vacuum Mains

Table 5-7 provides general guidelines for vacuum main slopes.

Table 5-7

Guidelines for Determining Vacuum Main Slopes

Level	0.20% slope until depth is unacceptable; then use lifts
Uphill	Use lifts spaced close together (see Table 4.6)
Downhill	Follow ground profile when ground >0.20% slope

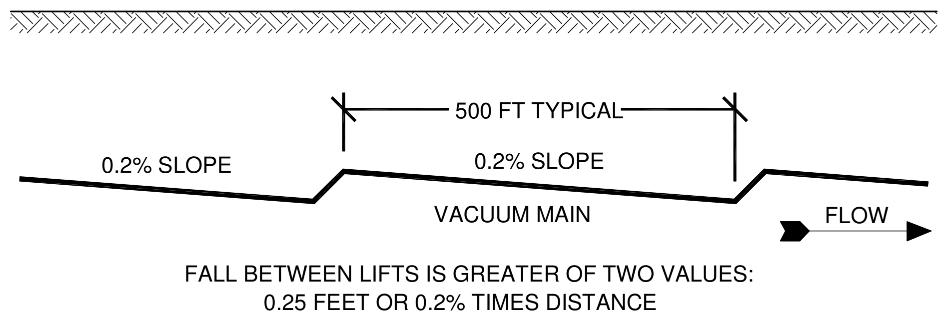


FIGURE 5-3: LEVEL TRANSPORT

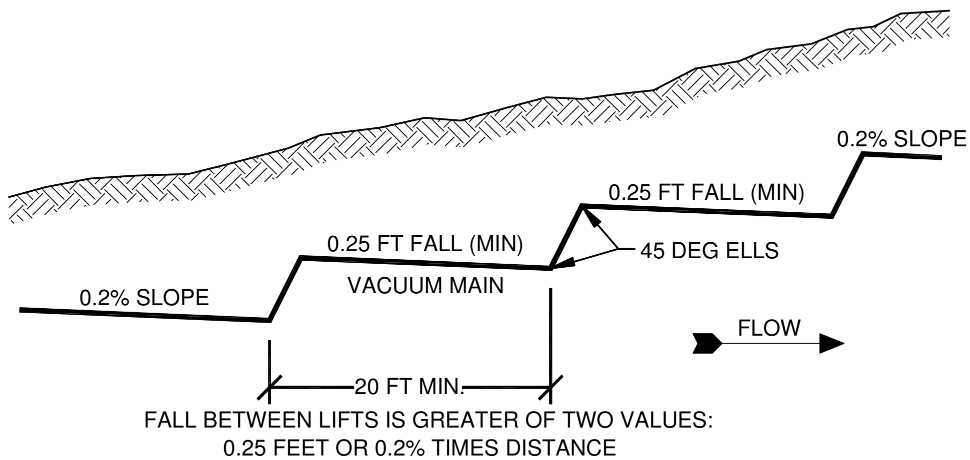


FIGURE 5-4: UPHILL TRANSPORT

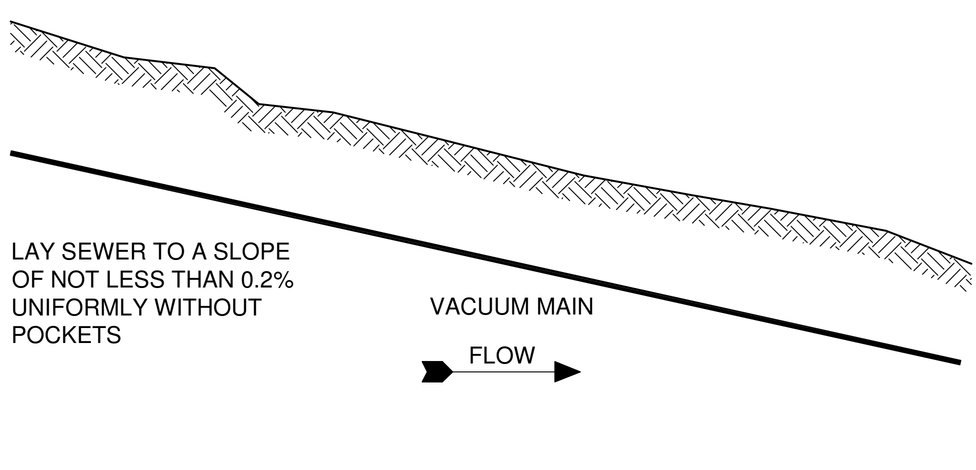


FIGURE 5-5: DOWNHILL TRANSPORT

Slope between lifts
For slope between lifts, Table 5-8 shows the distance at which the 0.20% slope, rather than the minimum fall, will govern the design for a given pipe diameter.

Table 5-8

Slopes Between Lifts

Pipe Diameter (in)	Minimum fall between lifts* Use greater value of (A) or (B) (A)	(B)	Distance at which (B) governs
3	0.20 ft	0.20% x distance	> 100 ft
4	0.25 ft	0.20% x distance	> 125 ft
6	0.25 ft	0.20% x distance	> 125 ft
8	0.25 ft	0.20% x distance	> 125 ft
10	0.25 ft	0.20% x distance	> 125 ft
12	0.25 ft	0.20% x distance	> 125 ft

* *When not between lifts, use 0.20% slope; distance measured in feet*

F. VACUUM SERVICE LATERAL (Pit to Main) DESIGN PARAMETERS

Vacuum service laterals connect the vacuum main to the valve pit and consist of 2 parts: the 3-in. rigid PVC vacuum lateral and the 3-in. Airvac flexible connector. Service laterals are 3 inches in diameter and are limited to one valve pit only. The type of pipe and fittings are the same as those used on the vacuum mains and branch lines.

When lifts are required in the 3-inch vacuum service lateral
If it is necessary to locate an Airvac valve with its invert lower than the main, the procedure shown in Figure 5-6 should be followed. Where this method is used, the maximum lift must not exceed the vacuum available in the main at the point of connection. Lifts used must be included when calculating the system line losses.

Table 5-9

3-inch Vacuum Service Lateral Design Parameters

Maximum number of 1'- lifts in service lateral	5 ea
Minimum distance from valve pit to 1st lift	5 ft
Minimum distance from last lift to main	5 ft
Minimum slope between lifts	0.20 ft or [0.2% x distance (ft)] (whichever is larger)

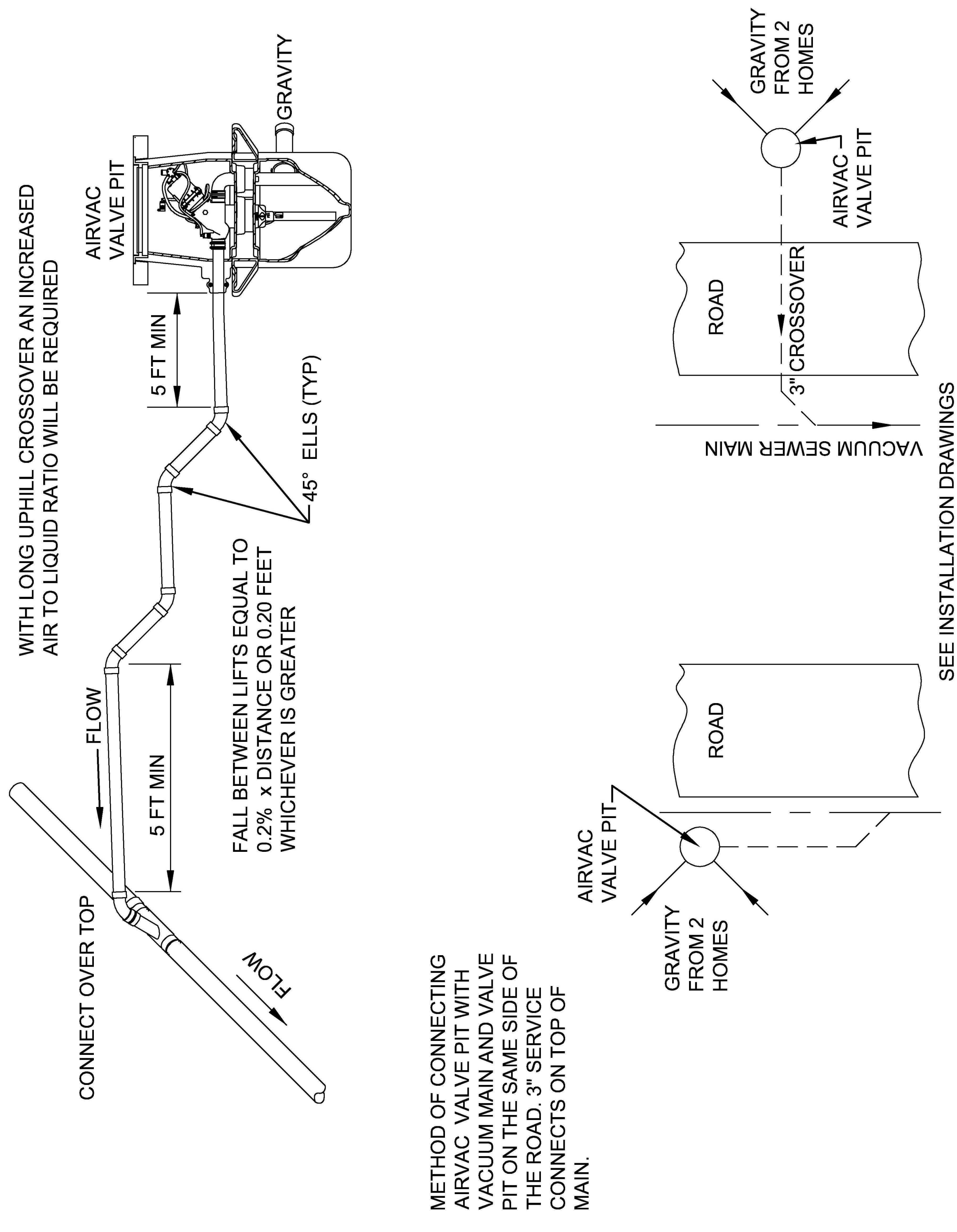


FIGURE 5-6: 3-IN. VACUUM SERVICE LATERAL WITH LIFTS

G. LINE CONNECTIONS

Two (2) types of connections are made to a vacuum sewer:

- Connections from a branch to a main
- Connections from a 3-in. vacuum service lateral (from a valve pit) to either a branch or main.

Tee fittings are not acceptable for use in either of these types of connections.

Connecting a branch to a main

Several configurations involving wyes and fittings have been used to connect a branch to a main. See Airvac's standard details for the various methods for connecting branch sewers to vacuum mains.

In one method, connections to the main are made "over-the-top," by using a wye fitting in the vertical position. Due to the restraints placed upon the depth of sewers by the connections entering "over the top", engineers should consider the ground cover required on service laterals.

In another method, the invert to invert spacing can be reduced by rolling the wye fitting to a 45° angle. This method is acceptable, provided the invert of the connecting pipe is above the crown of the main.

Note that 90° ells are not allowed in a vacuum system with one exception: the top of the suction pipe in the valve pit. Also, where a lift or profile change is required in a branch sewer prior to entering the main, it should be made 20 or more feet from the main.

Connecting a vacuum service lateral to a branch or main

Several configurations involving wyes and fittings have been used to connect a valve pit to a branch or main. See Airvac's standard details which show the various methods that are acceptable.

H. LOSSES DUE TO FRICTION

Friction losses are only calculated for sewers that are laid on a downward slope between 0.20% and 2.0% and are cumulative for each flow path from the furthest valve on the line to the vacuum station. Friction losses in sewers installed at greater than 2.0% percent are ignored.

Friction loss charts for SDR 21 PVC pipe and a 2:1 air/liquid ratio have been developed by Airvac. These charts were based on the following formula:

$$F = 2.75 \times 0.2083 \times (100/C)^{1.85} \times \frac{Q^{1.85}}{d^{4.8655}}$$

Where:

- F = friction loss (ft/100 ft)
- C = 150 for PVC
- Q = flow (gpm)
- d = inside pipe diameter (in.)

Table 5-10

PVC Pipe Sizes and
Related Airvac Design Information
C = 150

Pipe Type	Pipe Diameter (inches)	I.D. (inches)	(F=0.25) Rec'd Design Q (gpm)	(F=0.50) Absolute Max Q (gpm)
SDR 21	4	4.05	38	55
	6	5.96	105	152
	8	7.76	210	305
	10	9.67	374	544
	12	11.50	590	858
SCH 40	4	4.00	37	53
	6 *	6.03	108	157
	8 *	7.94	223	324
	10 *	9.98	406	591
	12 *	11.89	645	938

* These sizes not recommended in Schedule 40
Airvac recommends SDR 21 and maximum flow based on F = 0.25

Table 5-11

FRICTION LOSS TABLE
FOR 4 INCH PIPE

FLOW (gpm)	HEAD LOSS (ft/100 ft)		FLOW (gpm)	HEAD LOSS (ft/100 ft)		FLOW (gpm)	HEAD LOSS (ft/100 ft)
2	.0011		20	.0765		38	.2508
3	.0023		21	.0837		39	.2631
4	.0039		22	.0912		40	.2757
5	.0059		23	.0991		41	.2886
6	.0082		24	.1072		42	.3018
7	.0110		25	.1156		43	.3152
8	.0140		26	.1243		44	.3289
9	.0175		27	.1333		45	.3429
10	.0212		28	.1425		46	.3571
11	.0253		29	.1521		47	.3716
12	.0297		30	.1619		48	.3863
13	.0345		31	.1721		49	.4014
14	.0395		32	.1825		50	.4167
15	.0449		33	.1932		51	.4322
16	.0506		34	.2041		52	.4480
17	.0566		35	.2154		53	.4641
18	.0629		36	.2269		54	.4804
19	.0696		37	.2387		55	.4970

*SHADED AREAS NOT RECOMMENDED

Table 5-12

FRICTION LOSS TABLE
FOR 6 INCH PIPE

FLOW (gpm)	HEAD LOSS (ft/100 ft)	FLOW (gpm)	HEAD LOSS (ft/100 ft)	FLOW (gpm)	HEAD LOSS (ft/100 ft)
3	.0003	31	.0263	59	.0864
4	.0006	32	.0278	60	.0891
5	.0009	33	.0295	61	.0919
6	.0013	34	.0312	62	.0947
7	.0017	35	.0329	63	.0975
8	.0021	36	.0346	64	.1004
9	.0027	37	.0364	65	.1033
10	.0032	38	.0383	66	.1063
11	.0039	39	.0402	67	.1093
12	.0045	40	.0421	68	.1123
13	.0053	41	.0440	69	.1154
14	.0060	42	.0461	70	.1185
15	.0069	43	.0481	71	.1217
16	.0077	44	.0502	72	.1248
17	.0086	45	.0523	73	.1281
18	.0096	46	.0545	74	.1313
19	.0106	47	.0567	75	.1346
20	.0117	48	.0590	76	.1380
21	.0128	49	.0613	77	.1414
22	.0139	50	.0636	78	.1448
23	.0151	51	.0660	79	.1482
24	.0164	52	.0684	80	.1517
25	.0176	53	.0708	81	.1552
26	.0190	54	.0733	82	.1588
27	.0203	55	.0759	83	.1624
28	.0218	56	.0784	84	.1660
29	.0232	57	.0810	85	.1797
30	.0247	58	.0837	86	.1734

Table 5-12 (cont)

FRICTION LOSS TABLE
FOR 6 INCH PIPE

FLOW (gpm)	HEAD LOSS (ft/100 ft)		FLOW (gpm)	HEAD LOSS (ft/100 ft)		FLOW (gpm)	HEAD LOSS (ft/100 ft)
87	.1772		112	.2827		137	.4104
88	.1810		113	.2874		138	.4160
89	.1848		114	.2921		139	.4216
90	.1886		115	.2969		140	.4272
91	.1925		116	.3017		141	.4329
92	.1965		117	.3068		142	.4386
93	.2004		118	.3114		143	.4443
94	.2044		119	.3163		144	.4501
95	.2085		120	.3212		145	.4559
96	.2126		121	.3262		146	.4617
97	.2167		122	.3312		147	.4676
98	.2208		123	.3362		148	.4735
99	.2250		124	.3413		149	.4794
100	.2292		125	.3464		150	.4854
101	.2335		126	.3515		151	.4914
102	.2378		127	.3567		152	.4974
103	.2421		128	.3619		153	.5035
104	.2465		129	.3672		154	.5096
105	.2509		130	.3725			
106	.2553		131	.3778			
107	.2598		132	.3831			
108	.2643		133	.3885			
109	.2689		134	.3939			
110	.2734		135	.3994			
111	.2781		136	.4049			

*SHADED AREAS NOT RECOMMENDED

Table 5-13

FRICTION LOSS TABLE
FOR 8 INCH PIPE

FLOW (gpm)	HEAD LOSS (ft/100 ft)	FLOW (gpm)	HEAD LOSS (ft/100 ft)	FLOW (gpm)	HEAD LOSS (ft/100 ft)
85	.0470	113	.0796	141	.1199
86	.0480	114	.0809	142	.1214
87	.0491	115	.0822	143	.1230
88	.0501	116	.0835	144	.1246
89	.0512	117	.0849	145	.1262
90	.0522	118	.0862	146	.1278
91	.0533	119	.0876	147	.1295
92	.0544	120	.0889	148	.1311
93	.0555	121	.0903	149	.1327
94	.0566	122	.0917	150	.1344
95	.0577	123	.0931	151	.1361
96	.0589	124	.0945	152	.1377
97	.0600	125	.0959	153	.1394
98	.0612	126	.0973	154	.1411
99	.0623	127	.0988	155	.1428
100	.0635	128	.1002	156	.1445
101	.0647	129	.1017	157	.1462
102	.0658	130	.1031	158	.1480
103	.0670	131	.1046	159	.1497
104	.0683	132	.1061	160	.1514
105	.0695	133	.1076	161	.1532
106	.0707	134	.1091	162	.1550
107	.0719	135	.1106	163	.1567
108	.0732	136	.1121	164	.1585
109	.0745	137	.1136	165	.1603
110	.0757	138	.1152	166	.1621
111	.0770	139	.1167	167	.1639
112	.0783	140	.1183	168	.1657

Table 5-13 (cont)

FRICTION LOSS TABLE
FOR 8 INCH PIPE

FLOW (gpm)	HEAD LOSS (ft/100 ft)		FLOW (gpm)	HEAD LOSS (ft/100 ft)		FLOW (gpm)	HEAD LOSS (ft/100 ft)
169	.1676		197	.2225		225	.2846
170	.1694		198	.2246		226	.2869
171	.1713		199	.2267		227	.2893
172	.1731		200	.2288		228	.2916
173	.1750		201	.2310		229	.2940
174	.1769		202	.2331		230	.2964
175	.1788		203	.2352		231	.3988
176	.1806		204	.2374		232	.3012
177	.1825		205	.2395		233	.3036
178	.1845		206	.2417		234	.3060
179	.1864		207	.2439		235	.3084
180	.1883		208	.2461		236	.3108
181	.1903		209	.2483		237	.3133
182	.1922		210	.2505		238	.3157
183	.1942		211	.2527		239	.3182
184	.1961		212	.2549		240	.3206
185	.1981		213	.2571		241	.3231
186	.2001		214	.2594		242	.3256
187	.2021		215	.2616		243	.3281
188	.2041		216	.2639		244	.3306
189	.2061		217	.2661		245	.3331
190	.2081		218	.2684		246	.3356
191	.2102		219	.2707		247	.3382
192	.2122		220	.2730		248	.3407
193	.2142		221	.2753		249	.3432
194	.2163		222	.2776		250	.3458
195	.2184		223	.2799		251	.3484
196	.2204		224	.2822		252	.3509

*SHADED AREAS NOT RECOMMENDED

Table 5-14

FRICTION LOSS TABLE
FOR 10 INCH PIPE

FLOW (gpm)	HEAD LOSS (ft/100 ft)	FLOW (gpm)	HEAD LOSS (ft/100 ft)	FLOW (gpm)	HEAD LOSS (ft/100 ft)
200	.0784	236	.1065	272	.1386
201	.0792	237	.1074	273	.1395
202	.0799	238	.1082	274	.1404
203	.0806	239	.1091	275	.1414
204	.0814	240	.1099	276	.1423
205	.0821	241	.1108	277	.1433
206	.0829	242	.1116	278	.1443
207	.0836	243	.1125	279	.1452
208	.0843	244	.1133	280	.1462
209	.0851	245	.1142	281	.1472
210	.0859	246	.1151	282	.1481
211	.0866	247	.1159	283	.1491
212	.0874	248	.1168	284	.1501
213	.0881	249	.1177	285	.1511
214	.0889	250	.1185	286	.1520
215	.0897	251	.1194	287	.1530
216	.0904	252	.1203	288	.1540
217	.0912	253	.1212	289	.1550
218	.0920	254	.1221	290	.1560
219	.0928	255	.1230	291	.1570
220	.0936	256	.1239	292	.1580
221	.0944	257	.1247	293	.1590
222	.0952	258	.1256	294	.1600
223	.0959	259	.1266	295	.1610
224	.0967	260	.1275	296	.1620
225	.0975	261	.1284	297	.1630
226	.0983	262	.1293	298	.1640
227	.0992	263	.1302	299	.1651
228	.1000	264	.1311	300	.1661
229	.1008	265	.1320	301	.1671
230	.1016	266	.1330	302	.1681
231	.1024	267	.1339	303	.1692
232	.1032	268	.1348	304	.1702
233	.1041	269	.1357	305	.1712
234	.1049	270	.1367	306	.1723
235	.1057	271	.1376	307	.1733

Table 5-14 (cont)

FRICTION LOSS TABLE
FOR 10 INCH PIPE

FLOW (gpm)	HEAD LOSS (ft/100 ft)	FLOW (gpm)	HEAD LOSS (ft/100 ft)	FLOW (gpm)	HEAD LOSS (ft/100 ft)
308	.1744	344	.2139	380	.2572
309	.1754	345	.2151	381	.2584
310	.1765	346	.2162	382	.2597
311	.1775	347	.2174	383	.2610
312	.1786	348	.2186	384	.2622
313	.1796	349	.2197	385	.2635
314	.1807	350	.2209	386	.2648
315	.1818	351	.2221	387	.2660
316	.1828	352	.2232	388	.2673
317	.1839	353	.2244	389	.2686
318	.1850	354	.2256	390	.2699
319	.1861	355	.2268	391	.2711
320	.1871	356	.2280	392	.2724
321	.1882	357	.2291	393	.2737
322	.1893	358	.2303	394	.2750
323	.1905	359	.2315	395	.2763
324	.1915	360	.2327	396	.2776
325	.1926	361	.2339	397	.2789
326	.1937	362	.2351	398	.2802
327	.1948	363	.2363	399	.2815
328	.1959	364	.2375	400	.2828
329	.1970	365	.2387	401	.2841
330	.1981	366	.2399	402	.2854
331	.1992	367	.2412	403	.2867
332	.2003	368	.2422	404	.2880
333	.2015	369	.2436	405	.2894
334	.2026	370	.2448	406	.2907
335	.2037	371	.2460	407	.2920
336	.2048	372	.2473	408	.2933
337	.2060	373	.2485	409	.2947
338	.2071	374	.2497	410	.2960
339	.2082	375	.2510	411	.2974
340	.2094	376	.2522	412	.2987
341	.2105	377	.2534	413	.3000
342	.2116	378	.2547	414	.3014
343	.2128	379	.2559	415	.3027

*SHADED AREAS NOT RECOMMENDED

Table 5-15

FRICTION LOSS TABLE
FOR 12 INCH PIPE

FLOW (gpm)	HEAD LOSS (ft/100 ft)	FLOW (gpm)	HEAD LOSS (ft/100 ft)	FLOW (gpm)	HEAD LOSS (ft/100 ft)
400	0.1217	436	0.1427	472	0.1653
401	0.1222	437	0.1433	473	0.1659
402	0.1228	438	0.1439	474	0.1666
403	0.1234	439	0.1445	475	0.1672
404	0.1239	440	0.1451	476	0.1679
405	0.1245	441	0.1458	477	0.1685
406	0.1251	442	0.1464	478	0.1692
407	0.1257	443	0.1470	479	0.1698
408	0.1262	444	0.1476	480	0.1705
409	0.1268	445	0.1482	481	0.1712
410	0.1274	446	0.1488	482	0.1718
411	0.1279	447	0.1495	483	0.1725
412	0.1285	448	0.1501	484	0.1731
413	0.1291	449	0.1507	485	0.1738
414	0.1297	450	0.1513	486	0.1745
415	0.1303	451	0.1519	487	0.1751
416	0.1308	452	0.1526	488	0.1758
417	0.1314	453	0.1532	489	0.1765
418	0.1320	454	0.1538	490	0.1771
419	0.1326	455	0.1544	491	0.1778
420	0.1332	456	0.1551	492	0.1785
421	0.1338	457	0.1557	493	0.1791
422	0.1344	458	0.1563	494	0.1798
423	0.1349	459	0.1570	495	0.1805
424	0.1355	460	0.1576	496	0.1812
425	0.1361	461	0.1582	497	0.1818
426	0.1367	462	0.1589	498	0.1825
427	0.1373	463	0.1595	499	0.1832
428	0.1379	464	0.1601	500	0.1839
429	0.1385	465	0.1608	501	0.1846
430	0.1391	466	0.1614	502	0.1852
431	0.1397	467	0.1621	503	0.1859
432	0.1403	468	0.1627	504	0.1866
433	0.1409	469	0.1633	505	0.1873
434	0.1415	470	0.1640	506	0.1880
435	0.1421	471	0.1646	507	0.1887

Table 5-15 (cont)

FRICTION LOSS TABLE
FOR 12 INCH PIPE

FLOW (gpm)	HEAD LOSS (ft/100 ft)		FLOW (gpm)	HEAD LOSS (ft/100 ft)		FLOW (gpm)	HEAD LOSS (ft/100 ft)
508	0.1894		544	0.2149		580	0.2420
509	0.1900		545	0.2157		581	0.2427
510	0.1907		546	0.2164		582	0.2435
511	0.1914		547	0.2171		583	0.2443
512	0.1921		548	0.2179		584	0.2451
513	0.1928		549	0.2186		585	0.2458
514	0.1935		550	0.2193		586	0.2466
515	0.1942		551	0.2201		587	0.2474
516	0.1949		552	0.2208		588	0.2482
517	0.1956		553	0.2215		589	0.2490
518	0.1963		554	0.2223		590	0.2497
519	0.1970		555	0.2230		591	0.2505
520	0.1977		556	0.2238		592	.02513
521	0.1984		557	0.2245		593	.02521
522	0.1991		558	0.2253		594	.02529
523	0.1998		559	0.2260		595	.02537
524	0.2005		560	0.2268		596	.02545
525	0.2012		561	0.2275		597	.02553
526	0.2020		562	0.2283		598	.02561
527	0.2027		563	0.2290		599	.02568
528	0.2034		564	0.2298		600	.02576
529	0.2041		565	0.2305		601	.02584
530	0.2048		566	0.2313		602	.02592
531	0.2055		567	0.2320		603	.02600
532	0.2062		568	0.2328		604	.02608
533	0.2070		569	0.2336		605	.02616
534	0.2077		570	0.2343		606	.02624
535	0.2082		571	0.2351		607	.02632
536	0.2091		572	0.2358		608	.02640
537	0.2098		573	0.2366		609	.02648
538	0.2106		574	0.2374		610	.02656
539	0.2113		575	0.2381		611	.02664
540	0.2120		576	0.2389		612	.02673
541	0.2127		577	0.2397		613	.02681
542	0.2135		578	0.2404		614	.02689
543	0.2142		579	0.2412		615	.02697

*SHADED AREAS NOT RECOMMENDED

PROJECT ______________________________ AIRVAC® PROJECT # __________ STATION ______________

LINE ___________ AIR/LIQUID ___________ MAX FLOW __________ DATE ______________

STATION TO STATION	LINE LENGTH	Q MEAN	Q ACC'M	FRICT 100'	FRICT LOSS LINE	FRICT LOSS ACCUM	STATIC LOSS LINE	STATIC LOSS ACCUM	PIPE SIZE					NUMBER AIRVAC VALVES	HOMES
									4"	6"	8"	10"	12”		

FIGURE 5-7: FRICTION LOSS CALCULATION SHEET

I. LOSSES DUE TO LIFTS (STATIC LOSS)

Operating vacuum ranges of 16 to 20-in. Hg are typical for most modern vacuum systems. While deeper vacuum ranges are attainable, this range is generally considered the most practical in terms of equipment operating cost and dependability.

When considering the limit of water lifted by a vacuum, it is common to think in terms of a water manometer in which the liquid is lifted in a vertical column. The height of this column is in direct proportion to the difference between available atmospheric pressure and the sub-atmospheric pressure within the vacuum.

Basis of Design

In an Airvac vacuum system, the lower operating level of 16-in. Hg is used as the basis of system hydraulic design. In this case, a vertical column of liquid could be suspended 18 feet at sea level (1-in. Hg = 1.13' water).

Five (5) feet of this liquid column must be reserved for the vacuum valve operation and sump liquid evacuation. This results in 13 feet of liquid available for transportation within a vacuum system (Figure 5-8).

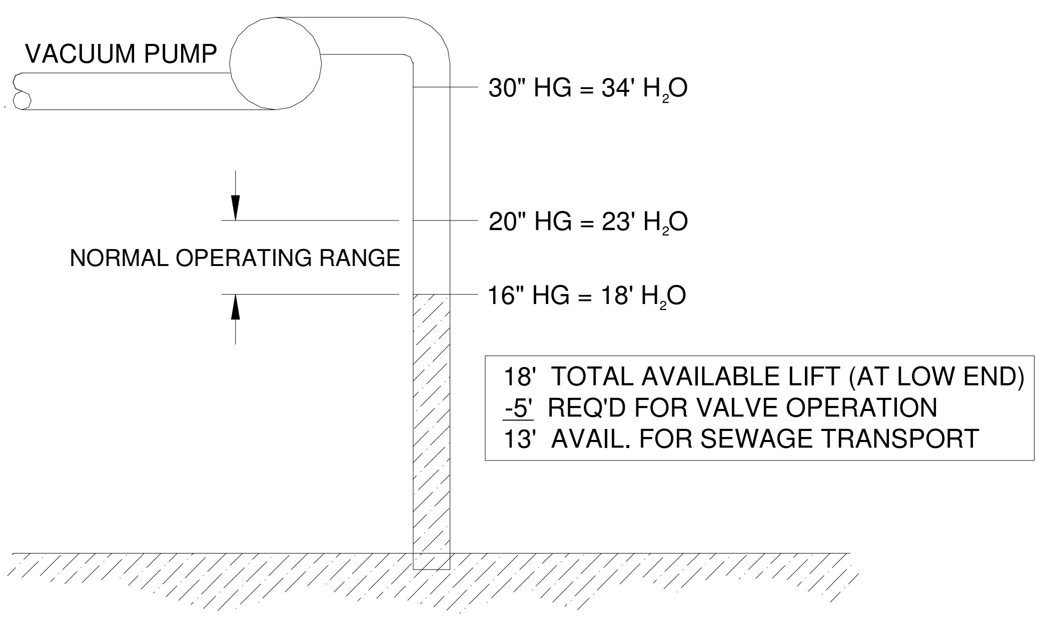


FIGURE 5-8: VACUUM LIFT CAPABILITY

Recommended lift heights

Static losses are those incurred by using lifts, or vertical profile changes. For efficient use of the energy available, lifts should be as small as possible. Numerous smaller lifts are recommended over one large lift. Table 5-16 shows the recommended lift height for various pipe sizes.

Table 5-16

Recommended Lift Height

Pipe Diameter (in)	Lift Height (ft)
3	1.0
4	1.0
6	1.5
8	1.5
10	1.5
12	2.0

In no case should a lift exceeding 3 feet be made without consulting the Airvac technical staff.

Static loss calculations

Static losses are calculated by subtracting the pipe diameter from the lift height (Figure 5-9).

Static Loss = Lift Height - Pipe Diameter

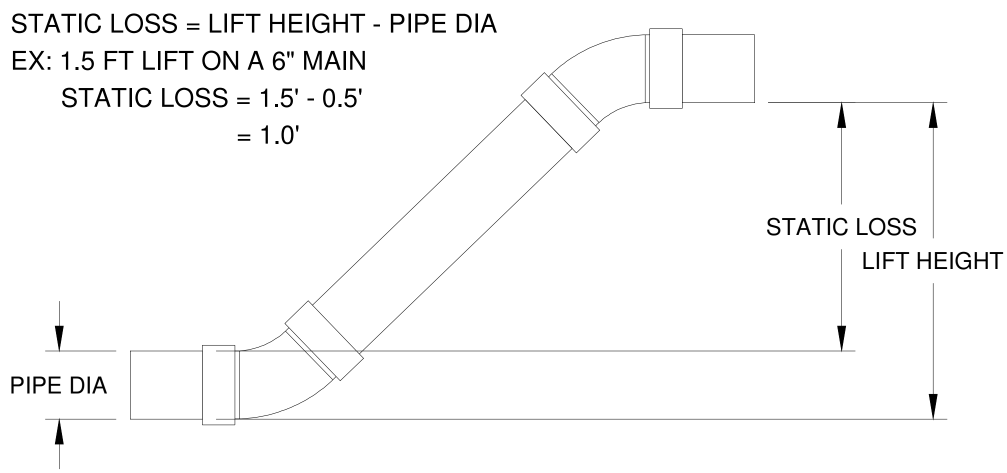


FIGURE 5-9: STATIC LOSS DETERMINATION

Recommended static loss limits
Empirical studies currently indicate that system performance may be grouped as follows:

Table 5-17

Static & Friction Losses: Design Guidelines

Group	Static Loss (ft)	Friction Loss (ft)	Operation during Normal conditions	Recovery from temporary A/L imbalance
A	0.0 -13.0	< 5	Dependable	Automatic recovery without disruption of service
B	13.1- 16.0	< 5	Dependable if a) high static loss is limited to 1 or 2 branches & b) optimum placement of valves and lifts are considered	Automatic recovery with momentary low vacuum at line extremities
C	> 16.0	< 5	Reasonably dependable if : a) high static loss is limited to 1 or 2 branches & b) optimum placement of valves and lifts are considered	Recovery relies on the injection of atmospheric air at selected points to restore adequate vacuum to line extremities

Airvac recommends that systems be designed with the guidelines stated in group A:

13 Feet of Vacuum Loss due to Lifts (Max)
5 Feet of Vacuum Loss due to Friction (Max)

The static loss and friction losses are separate calculations and are a summation of losses for each flow path. Simply stated, a flow path is the piping through which liquid will travel from the last Airvac valve to the vacuum station.

Airvac should be consulted for any design following the guidelines of group B or C.

Observations from in-house hydraulic studies

The idea behind the Airvac saw-tooth profile is to maintain an open passageway throughout the top portion of the piping network. If this is the case, the same level of vacuum will be present at the end of the system as exists at the vacuum station.

The Airvac system operates on the concept of moving a mixture of air and liquid only part of its intended travel distance. As propulsive forces are diminished, the liquid and air will separate, and the liquid will come to rest at low points within the system. Subsequent Airvac valve cycles will then boost this liquid downstream to a new low point and the process repeats itself until the liquid enters the vacuum station.

The only time a vacuum loss occurs is when liquid is suspended within a vertical lift or when it is in motion; rarely will these events occur simultaneously.

Whether or not liquid is suspended in lifts is a function of many factors: pipe diameter, pipe slope, air-to-liquid ratio, number of valves opening at a given moment, and so on. The distance liquid travels, is also a function of many factors. Due to the uncertainty of predicting the exact occurrence of so many variables, previous design limits have been based on the worst-case scenario, that is, that all lifts are completely filled or saturated.

Substantial data has been gathered from operating vacuum systems to more accurately predict exactly where and when these variables will occur. While these studies remain on-going, it has become obvious that the occurrence of lift saturation is rare and normally associated with a temporary air to liquid imbalance.

The ability of a vacuum system to automatically recover from such an imbalance (thereby restoring normal vacuum to line extremities) is the actual limit of vacuum line design. During these brief periods, it has been shown that all losses within the system are associated with suspended liquid with very little friction loss occurring. This is also supported by the fact that little or no flow takes place.

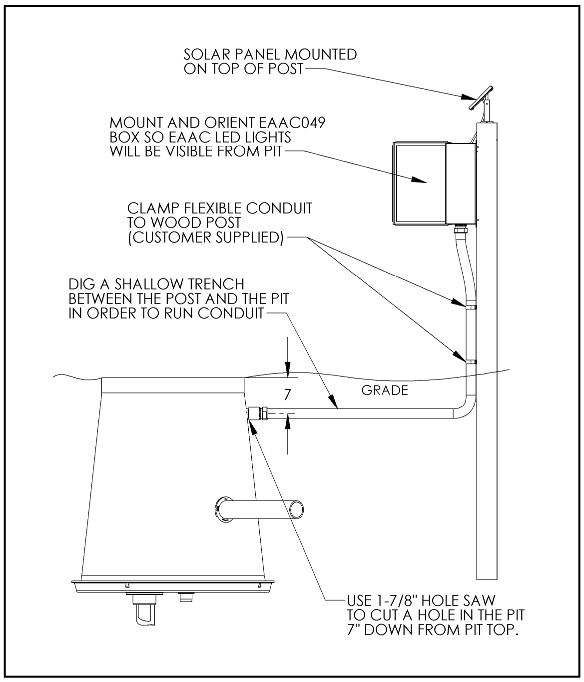
Widespread use of deep valve pits

For any single flow path where more than 25% of the valve pits are of the deep variety (8-ft and/or 10-ft deep pits), the allowable static loss of that vacuum main may need to be reduced from 13 ft. to a lower amount to account for the additional lift within the valve pit. Consult Airvac's Engineering Department for details.

<u>Electronic Air Admission Control (EAAC)</u>

The Electronic Air Admission Control (EAAC) is an accessory for a typical 3-in. Airvac vacuum valve. This device monitors line vacuum and will open if vacuum falls below a pre-set limit for an extended period. The opening of this valve injects large quantities of atmospheric air to boost liquid through various lifts and downstream towards the vacuum station. The result is an increase of available vacuum for valve operation.

While, the primary purpose of the EAAC is to improve the transport characteristics of a system that is already in operation, occasionally this device can be included as a design feature when static losses are slightly more than the recommended 13 feet. In these cases, the EAAC device may be needed to insure adequate vacuum is available for those sections of vacuum lines where the 13-foot limit has been exceeded. Since there are limits to the use of these devices, Airvac should be involved in the placement and parameters for their use. The minimum vacuum pump capacity when utilizing EAAC units is 305 acfm.



NOTE: See Chapter 8 for a discussion on Airvac's SMART system which is a state-of-the-art alternative to using an EAAC.

J. PIPE VOLUME

As discussed in Chapter 3, it is necessary to calculate the total connected pipe volume, expressed in gallons, for use in the vacuum pump sizing process. Section L.7 in this chapter shows the pipe volume expressed in ft^3/ft for the various pipe sizes based on the ID of SDR 21 pipe. To convert to pipe volume expressed in gallons, multiply these factors by the length of pipe and then by 7.48.

PROJECT____________________ PROJECT NUMBER____________

STATION NUMBER____________ DATE______________________

LINE	4" PIPE	6" PIPE	8" PIPE	10" PIPE	12" PIPE	NUMBER SERVICE LATERALS	NUMBER AIRVAC VALVES	HOMES
TOTALS								
				AVERAGE SERVICE LATERAL LENGTH				
				TOTAL 3" PIPE				

(VOLUME OF PIPEWORK: BASED ON SDR-21 PVC PIPE)

Vp = (.0547 x Length 3") + (.0904 x Length 4") + (.1959 x Length 6") + (.3321 x Length 8") + (.5095 x Length 10") + (.7260 x Length 12") ft^3

Vp = (______ + ______ + ______ + ______ + ______ +______) ft^3

Vp = 7.48 gal/ft^3 x (________) ft^3 = ___________ gal

$^2/_3$ Vp = _______ gal

FIGURE 5-10: PIPE VOLUME CALCULATION SHEET

K. FLOW FROM AN EXISTING GRAVITY SEWER

Perhaps no one single factor has resulted in more problems with vacuum systems than excessive flow from an existing gravity system entering a vacuum system via buffer tank(s).

There have been several isolated cases of severe system problems caused by excessive flow that entered from existing gravity systems. In the most extreme case, a system could be totally out of operation resulting in house backups. Obviously, this is a situation Airvac wants to avoid.

One problem is that it is difficult to accurately predict the flow that can be expected from existing gravity systems. With new construction, one can accurately predict average and peak flow rates and design the vacuum mains and vacuum station accordingly. However, with an existing system, another element is introduced into the equation: I&I. In these cases, Airvac's experience is that the consultant usually does one of the following during design:

- I&I is either not considered or is understated. If it occurs when the system is on-line, the system does not function properly because it is undersized. ***Result: During normal flow periods the system works fine, but during rain events it may experience problems.***

- To anticipate I&I, the designer overstates its magnitude. Larger vacuum mains, a larger collection tank and larger and possibly more vacuum pumps are used. If I&I is not of the magnitude anticipated, the system may not function properly during normal operation because it is oversized (flow transport is sluggish, problems occur at the vacuum station, etc.). ***Result: System may work fine during rain events, but system operation may be inefficient during normal periods***. Additionally, there are significant additional costs, both capital and O&M, associated with the larger system components.

Obviously, neither of the above situations is acceptable. Should it be possible to accurately predict I&I, it may be that this flow can be considered in a vacuum system. However, before Airvac will consider this, an analysis of the existing gravity system must be done. As a minimum, this would include having flow records that identify the magnitude of flow that can be expected during normal periods as well as rain events (minimum 1 year of flow data). Even then, should there be a large difference between normal daily flow and flow during rain events, Airvac would recommend against accepting this flow.

L. SUMMARY OF VACUUM MAIN DESIGN FUNDAMENTALS

1. SLOPES:

   a. Use natural ground slope if greater than 0.2%
   b. Use 0.2% slope for flat terrain
   c. Use saw tooth profile for uphill transport
   d. Use 0.2% slope at 50-ft minimum prior to first lift in any series

2. FALL BETWEEN LIFTS: Use larger of two (2) values

   a. 0.20% x Length
   b. 0.20 ft. Fall for 3-in. vacuum service lines if lifts are less than 100 lf apart.
   c. 0.25 ft. Fall for ALL Vacuum Mains if lifts are less than 125 lf apart.

3. LIFTS:

   a. Use 1'-0" for 3-in. or 4-in. pipe
   b. Use 1'-6" for 6-in. or larger pipe
   c. Static loss = Lift Height - Pipe Diameter
   d. Maximum vacuum loss due to lifts from any Airvac valve to the vacuum station = (13 ft Static Loss + 5 ft Friction Loss)
   e. Maximum series of lifts = 5. Separate one series of 5 lifts from the next lift or series of lifts by at least 100 ft of vacuum main. In addition, there must be at least 1 energy input in the zone of separation.
   f. First lift on a branch minimum 20 lf from connection to main.

4. CONNECTIONS:

   a. Use wye connectors for all branch and lateral connectors, wye may be vertical or at 45° angle
   b. Use 45° ells for 4" and larger connectors and any directional change
   c. Recommended minimum Invert to Invert elevation difference for connections:

4 x 3 = 0.66 ft	6 x 3 = 0.84 ft	8 x 3 = 1.40 ft
4 x 4 = 0.71 ft	6 x 4 = 0.85 ft	8 x 4 = 1.40 ft

5. FLOW LIMITS: (Maximum Friction Loss not to exceed 5 ft)

3-in. = 3 gpm
4-in. = 38 gpm
6-in. = 106 gpm
8-in. = 210 gpm
10-in. = 375 gpm
12-in. = 590 gpm

6. MAXIMUM LINE LENGTHS:

3-in. = 300 lf
4-in. = 2,000 lf
6-in. & Larger determined by static limits

7. PIPE VOLUMES

Pipe Size	Volume per foot (vf) ft^3/ft
3 inches	.0547
4 inches	.0904
6 inches	.1959
8 inches	.3321
10 inches	.5095
12 inches	.7260
Volume in a specific size of pipe is determined by multiplying the length of pipe by the appropriate vf factor above: L x vf = ft^3 The volume of 300 lf of 6" pipe is therefore: 300 x .1959 = 58.77 ft^3.	

8. DIVISION (ISOLATION) VALVES

a. Place a division valve for each branch vacuum sewer near its connection to the vacuum main line.

b. Place division valves for vacuum main lines at 1,500-foot centers or near branch connections.

M. DO'S AND DON'TS

Table 5-18

Do's and Don'ts: Vacuum Main Design

DON'T DO THIS:	DO THIS:
Exceed 13.0 feet static loss on any flow path	Contact Airvac if static loss of 13.0 feet or less is not attainable
Exceed 5.0 friction loss on any flow path	Increase pipe size if necessary
Design more than (5) lifts in any series	Separate a series of (5) lifts from the next lift or series of lifts by at least 100 ft of vacuum main and insure that at least 1 energy input is in the zone of separation
Design a lift greater than 3 ft without first contacting Airvac	Use multiple, smaller lifts
Use 0.20% slope between lifts when distance between lifts is < 125 ft.	Use 0.25 ft of fall between lifts when distance between lifts is < 125 ft.
Slope a main greater than 0.20% immediately prior to a series of lifts	Use a minimum of 50 lf of main sloped at 0.20% prior to a series of lifts
Use more than 2000 lf of 4" vacuum sewer at the end of any vacuum line	Increase pipe size to 6-in.
Design a vacuum system with all flow in a single vacuum main	Divide the system into zones by using a multiple vacuum main concept
Design long stretches of vacuum mains without valve pit connections	Install a valve pit or other means of energy input at regular intervals
Design a system that accepts flow from an existing gravity sewer via buffer tanks without first consulting Airvac	Serve by other means unless gravity flow and I&I can be accurately predicted

CHAPTER 6
VALVE PITS

A. VALVE PIT ARRANGEMENTS

Airvac has three types of valve pits: 1-Piece pits, 2-Piece pits and 2-Piece cold weather pits. These are made of a PE material and available in the following sizes:

Table 6-1

Airvac Valve Pit Types

Pit Type	Airvac Model No	Nominal Pit Depth	Pit Description	Rec'd Max # Conn	Depth to stub-out invert
Shallow	VP3030P1	5.0 ft	1-piece	2	3.71 ft
Standard	VP4830P1	6.5 ft	1-piece	4	5.21 ft
Standard	VP3042P2	6.0 ft	2-piece	4	5.00 ft
Standard	VP3042CW	6.0 ft	2-piece Cold Weather	4	5.00 ft
Deep	VP4842P1	7.5 ft	1-piece	4	6.21 ft
Deep	VP5442P2	8.0 ft	2-piece	4	7.00 ft
Deep	VP5442CW	8.0 ft	2-piece Cold Weather	4	7.00 ft
Extended	VP7842P2	10.0 ft	2-piece	4	9.00 ft
Extended	VP7842CW	10.0 ft	2-piece Cold Weather	4	9.00 ft

Note: The 2-piece PE/FRP hybrid valve pit (Model H) with a PE sump and fiberglass cone (5 ft, 6 ft, 8 ft, & 10 ft depths) has been replaced by the 2-Piece PE pit but remains available upon request.

<u>VALVE PIT MODEL DESIGNATIONS</u>

4830P1

- Type of pit (P1=1 piece; P2= 2 piece, CW=cold weather)
- Depth of top chamber (in)
- Depth of sump (in)

Special notes
For all valve pit types, the following applies:

1. The maximum combined peak flow to these valve pit types is limited to 3 gpm. For larger water users with peak flows in excess of 3 gpm, a buffer tank is used.

2. The sumps to these valve pit types can physically accept up to 4 incoming lines, subject to the 3 gpm maximum (see Note 3).

3. One of the 4 sump openings should be reserved for the 6" Air Terminal connection, reducing the maximum possible number of connections from 4 to 3. The manifolding of a building sewer to the Air Terminal outside the sump is not recommended; however, if this is necessary due to space limitations, it can be done but with certain restrictions. Contact Airvac's Engineering Department for guidance.

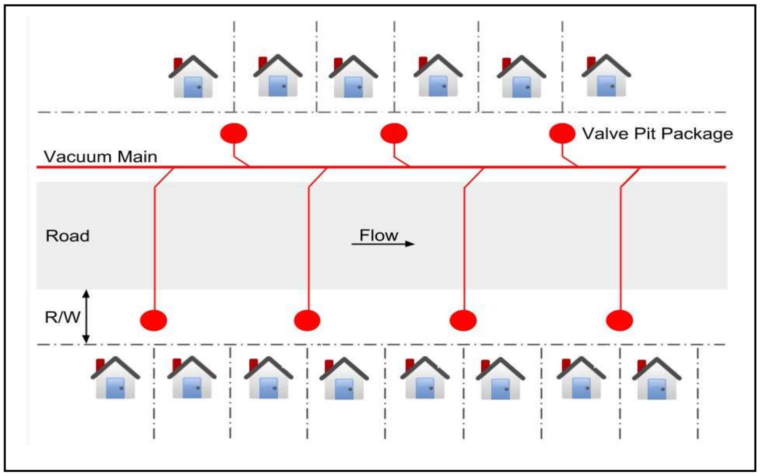
Choice of pit type & depth
The choice of valve pit types is made by the design engineer. There are advantages unique to each type relating to storage, shipping, installation, etc. In general, Airvac recommends using the 2-piece pit.

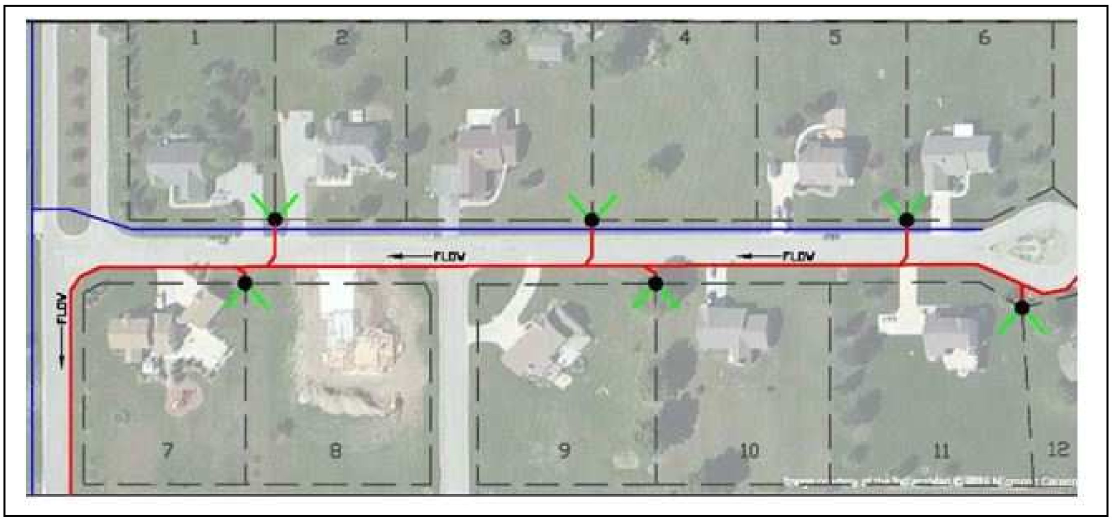
Water in the top chamber does not affect the valve operation of the Airvac valve as it was designed to function while submerged. For cold climates with extended periods of freezing temperatures, Airvac recommends using the cold-weather valve pit, which utilizes the 2-piece pit with several modifications, including an insulating layer in the cone top and an insulated lid insert.

After it is determined which houses will share a pit at a certain location, the depth of the valve pit must be determined. This should be done by the design engineer during the design phase and clearly marked on the construction drawings. The valve pit must be deep enough to allow flow by gravity from the house(s) that are connected to it, with distance from the house to pit and minimum slope requirements considered.

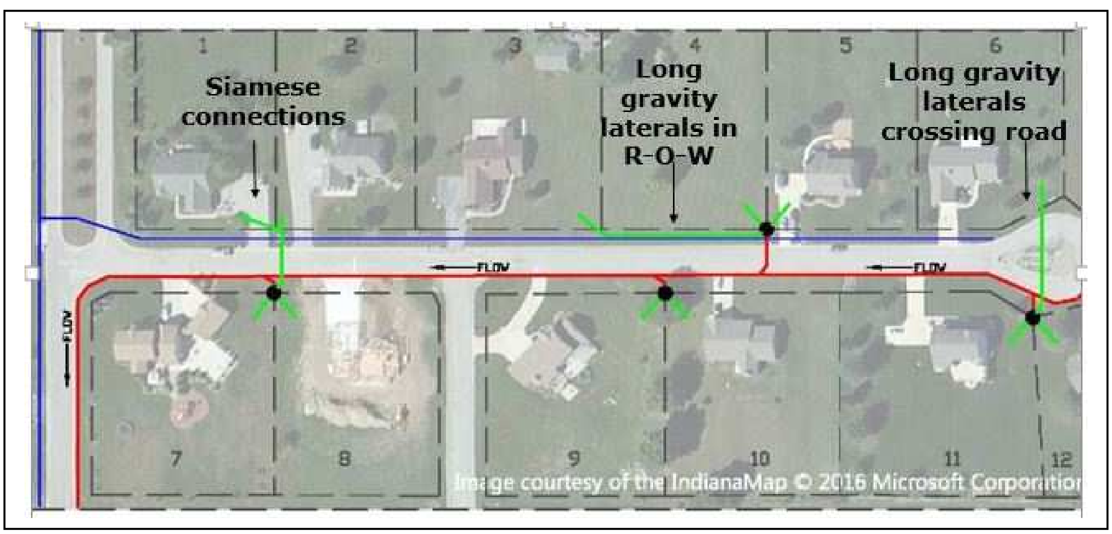
Pit sharing (house to pit ratio)
Up to four separate building sewers can be connected to one sump, however, this is rarely done as property lines considerations, septic tank locations and other factors may render this impractical.

The most common valve pit sharing arrangement is for two adjacent houses to share a single valve pit. As a rule, Airvac recommends a maximum house to ratio of 2.5: 1 on a system-wide basis (example: project serves 500 houses; at least 200 valve pits are required).

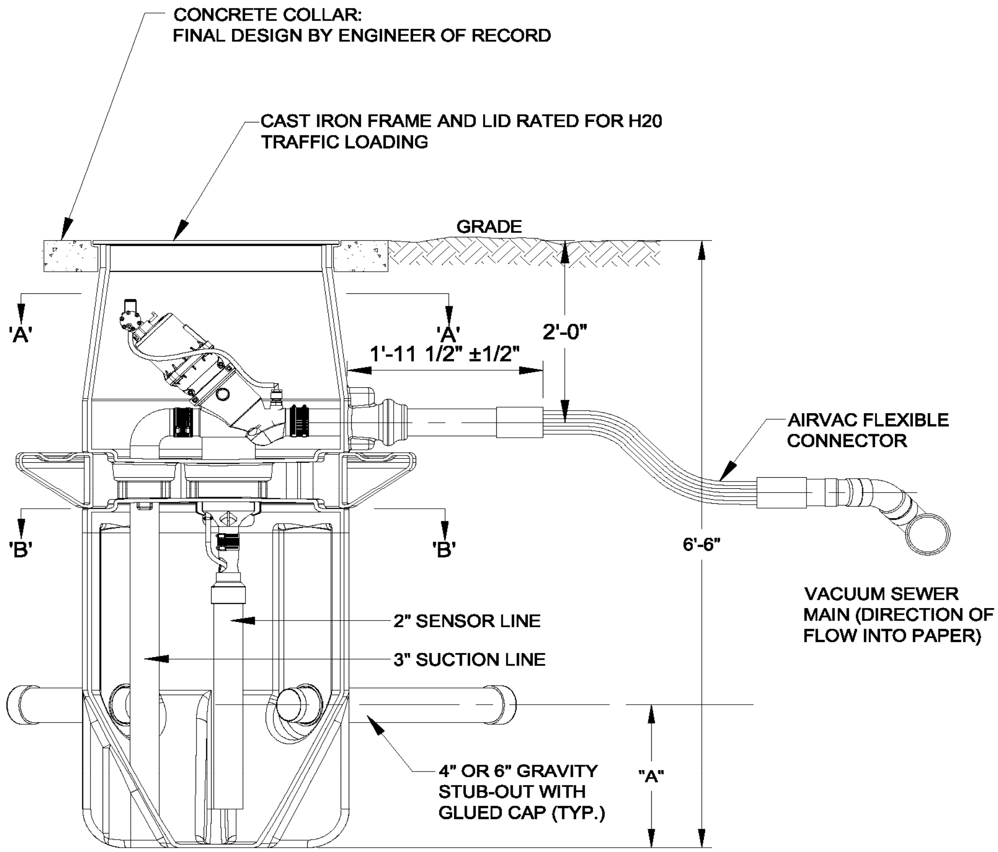




Typical valve pit sharing (recommended)

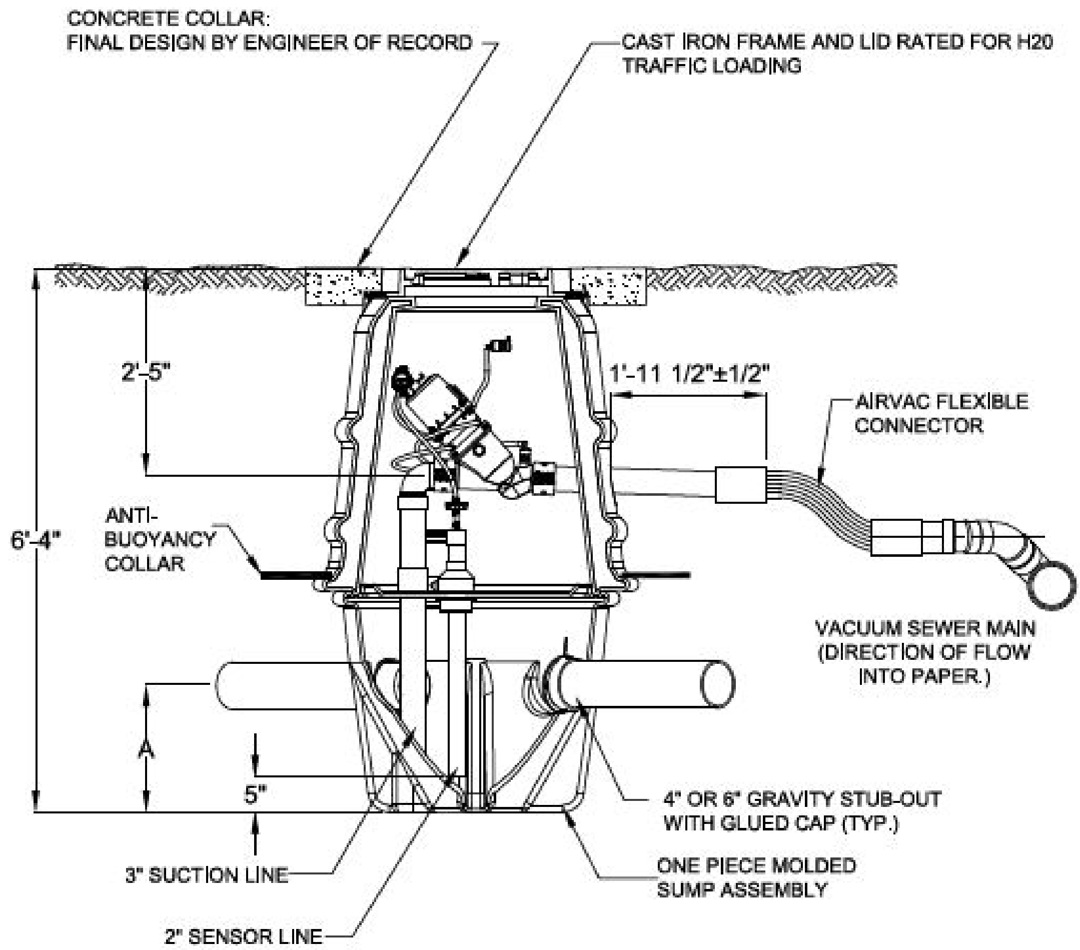


Examples of oversharing pits (not recommended)



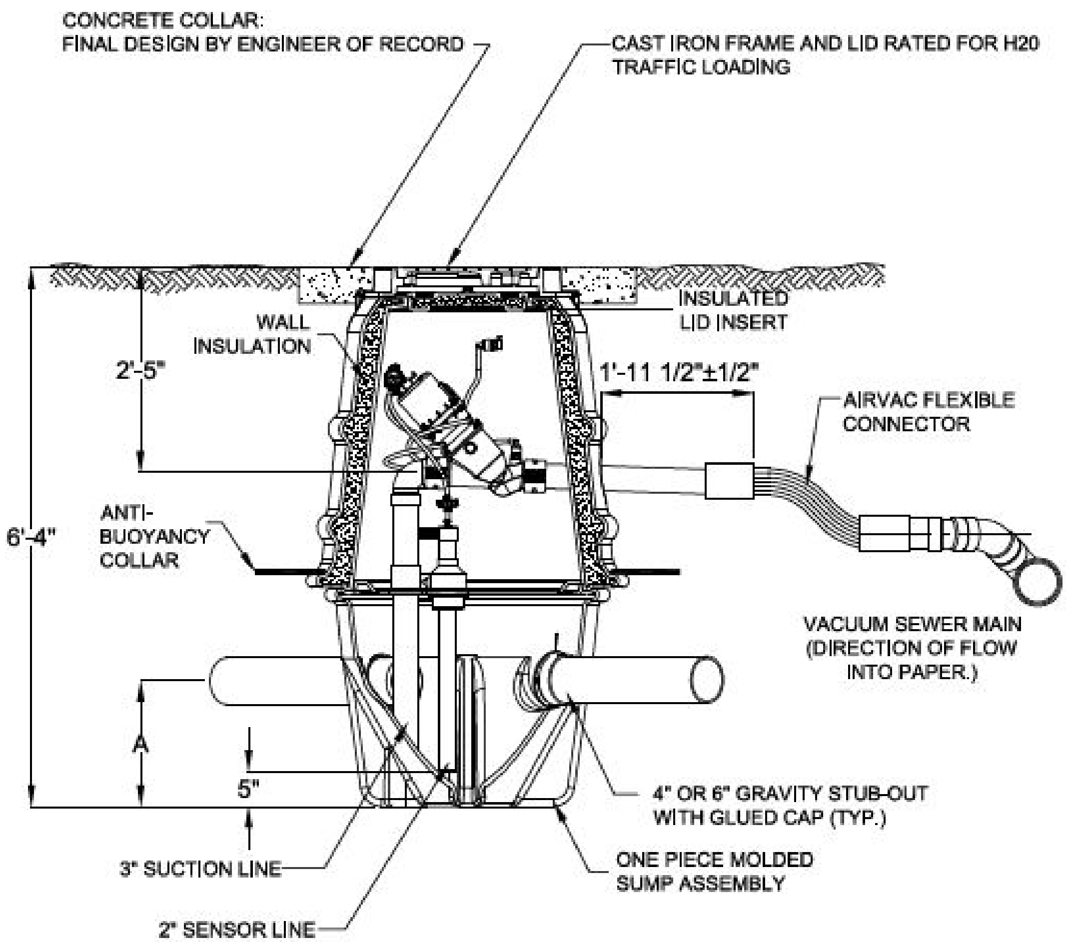
	DIM. "A"
4" GRAVITY	1'-6"
6" GRAVITY	1'-7"

FIGURE 6-1: AIRVAC 1-PIECE PIT (6.5')



	4" GRAVITY	6" GRAVITY
DIM "A"	1'-6"	1'-7"

FIGURE 6-2: AIRVAC 2-PIECE PIT (6')



	4" GRAVITY	6" GRAVITY
DIM "A"	1'-6"	1'-7"

FIGURE 6-3: AIRVAC 2-PIECE COLD WEATHER VALVE PIT (6')

B. COMPONENTS COMMON TO ALL PIT TYPES

3-inch Valve
The Airvac 3-inch vacuum valve is vacuum operated on opening and spring assisted on closing. System vacuum ensures positive valve seating. The valve has a 3-inch full-port opening, is made of glass filled polypropylene, and has a stainless-steel shaft, delrin bearing and elastomer seals.

The 3-inch vacuum valve is equipped with a rolling diaphragm-type vacuum operator and is capable of overcoming all sealing forces; and of opening using vacuum from the downstream side of the valve. All materials of the valve are chemically resistant to normal domestic sewage constituents and gases. Recent changes to the plunger included the elimination of exposed metal parts in order to prevent any freezing issues.

The Airvac 3-inch vacuum valve and controller combination requires 5-in. Hg vacuum for operation and to avoid low air-to-liquid ratios. The lower the vacuum level, the less differential (atmospheric pressure to line vacuum) exists. This equates to less air entering the system resulting in lower line velocities and sluggish flow characteristics.

Valve capacity: Chapter 7 contains a detailed discussion of the 30 gpm rated capacity of the Airvac 3-inch valve and when that capacity is possible. Note that the **rated capacity of the valve** is not to be confused with the **recommended design capacity of the valve pits.**

To ensure proper air-to-liquid ratios, Airvac recommends a maximum peak flow of 3 gpm be used for all valve pits serving residential customers. Buffer tanks may be sized using higher design capacities. Table 6-1 presented earlier in this chapter shows the recommended maximum # of connections for the various pit types.

Size: Many states do not have vacuum sewer regulations. Some of those that do, apply concepts of the Ten State Standards that advocate the ability to pass a 3-inch solid through any part of a sewage collection and treatment system. In addition, some plumbing codes have provisions that prohibit restrictions less than 3 inch downstream of any toilet.

To be consistent with industry standards, Airvac's vacuum valve was designed to be a full-port 3-inch valve capable of passing a 3-inch solid while matching the outside diameter of 3-in. PVC SDR pipe.

Pressure loss through the Airvac 3-inch vacuum valve: The driving force in a vacuum system is the pressure differential that exists between atmosphere and vacuum in the system. This differential occurs when the valve opens. As a result, the only place to impart energy in a vacuum system is at the valve itself. Any loss through the valve further depletes this energy resulting in less available for transport within the pipeline. This is especially critical considering that this loss occurs at every valve and during each valve cycle.

The flow coefficient (C_v factor) is that flow rate (gpm) which would yield a head loss of 1 psi. The higher the Cv factor, the less the head loss is through the valve. Airvac continually makes modifications to its 3-inch vacuum valve to keep friction loss to an absolute minimum and to have the highest C_v factor of any vacuum valve currently on the market.

Controller
The Airvac HP Controller/sensor is the key component of the Airvac 3-inch vacuum valve. The device relies on three forces for its operation: pressure, vacuum, and atmosphere. As the sewage level rises in the sump, it compresses air in the sensor tube. This pressure initiates the opening of the valve by overcoming spring tension in the controller and activates a three-way valve. Once opened, the three-way valve allows the controller/sensor to take vacuum from the downstream side of the valve and apply it to the actuator chamber to fully open the valve. The controller/sensor can maintain the valve fully open for a fixed period, which is adjustable over a range of 3 to 10 seconds. After the preset time has elapsed, atmospheric air is admitted to the actuator chamber permitting spring assisted closing of the valve.

The Airvac 3-inch vacuum valve controller is chemically resistant to sewage and sewage gases and is capable of operating when submerged in water. The Airvac valve pit was designed so that a very repeatable, specific amount of liquid is withdrawn on each cycle (10 gallons). The air cycle of the controller changes as vacuum levels fluctuates. With a varying amount of air and a specific amount of liquid, the air-to-liquid ratio will also fluctuate.

In-sump breather
The controller requires a source of atmospheric air to the actuator chamber permitting spring assisted closing of the 3-inch vacuum valve. Without this air, the valve would remain in the open position. The in-sump breather uses atmospheric air from the sump and the Airvac 6-inch Air Terminal (or its associated 4-inch gravity building sewer and 4-inch air intake). The in-sump breather is designed to protect the controller from unwanted liquid during system shut-downs and restarts. It also prevents sump pressure from forcing the vacuum valve to open during low vacuum conditions and provides positive sump venting regardless of traps in the gravity service line. *Note: In the one-piece pit, the in-sump breather is combined with the 3-inch sensor line as a single unit.*

Airvac Flexible Connector

The Airvac Flexible Connector is a standard item supplied with the valve pit. The flexible connector uses a special 3" flexible PVC hose which eliminates the difficulty experienced in earlier vacuum systems that used rigid pipe to connect two fixed points at different locations/elevations. Prior to the advent of the Airvac flexible connector, it was common for multiple fittings to be used, some of which were deflected beyond an acceptable range, to make this connection. The result was a vacuum leak, or worse, a line break caused by overstressing of the joint.

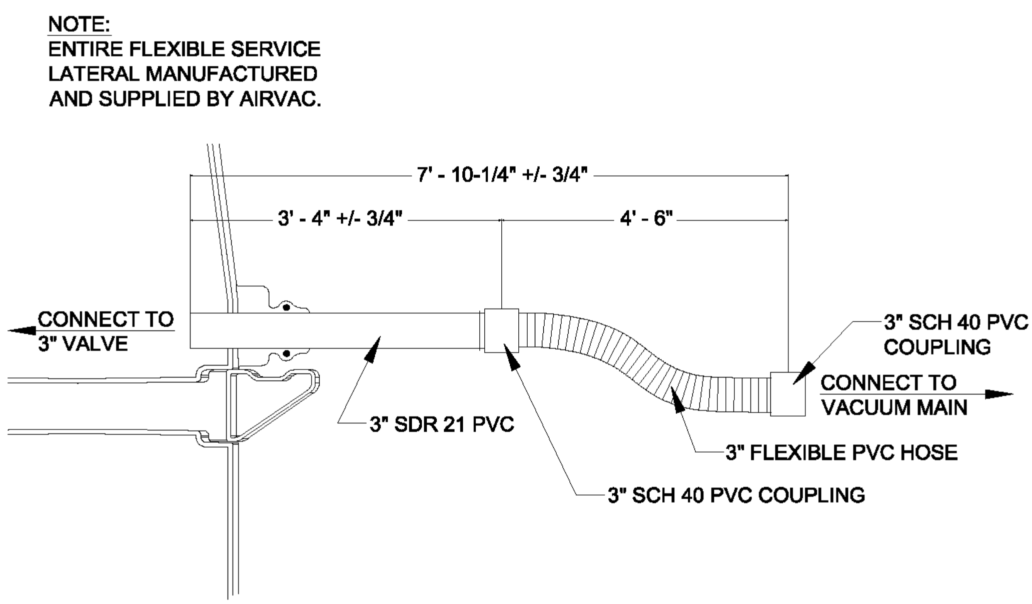


FIGURE 6-4: AIRVAC FLEXIBLE CONNECTOR

Connections at both ends of the flexible connector are the same as with PVC pipe. The use of an Airvac flexible connector virtually eliminates stress-related leaks caused by poor workmanship or ground settlement.

4-inch or 6-inch Stub-Out

To minimize the risk of damage to the valve pit during homeowner connection to the system, a stub-out pipe of sufficient length, typically 6 feet from the valve pit, is recommended. The orientation of the valve pit as it relates to the house and the wye connection varies according to the number of connections to the pit with the gravity stub-outs always at a 45-degree angle to the vacuum service line exiting the valve pit (see Figure 6-5)

The Airvac valve pit can accept either 4-inch or 6-inch pipe from the house. If 4-inch is used, the centerline of the 4-inch stub-out will be 18 inches above the bottom of the valve pit sump. If 6-inch is used, this dimension is 19-inches. This results in the same stub-out invert no matter which size pipe is used.

If the building sewer piping network does not have a cleanout within it, one should be placed outside and close to the home. Some agencies prefer having a cleanout at the dividing line to establish the point at which the agency's maintenance begins. This typically would be at the end of the stub-out pipe.

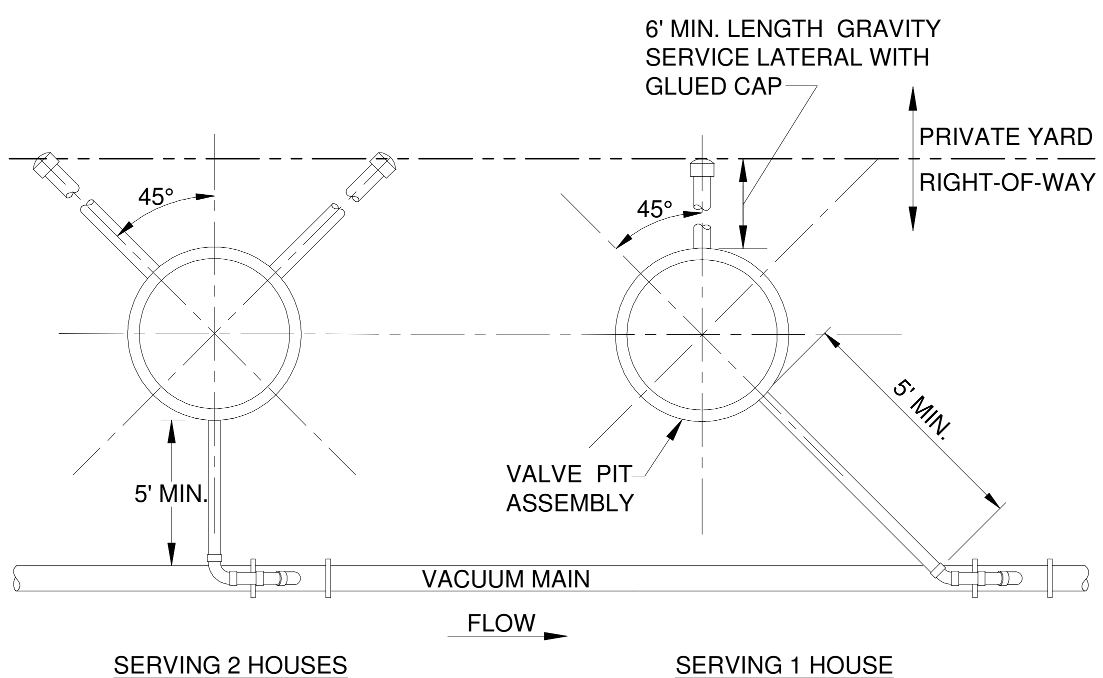


FIGURE 6-5: TYPICAL CONFIGURATIONS FOR GRAVITY CONNECTIONS

Valve pit covers: traffic rated

Cast iron covers and frames, designed for H-20 traffic loading, are used for all valve pit installations. Before Airvac endorses the use of a casting vendor, an Airvac valve pit fitted with the vendor's frame and cover is tested by an independent testing lab for H-20 loading. Contact Airvac's engineering department for a list of those vendors that supply traffic-rated frames and covers that match the dimensions of Airvac valve pits.

For traffic-rated covers, the frame weight is generally 76 lbs. and the lid weight about 105 lbs. Unless otherwise specified, the words "Airvac SEWER" in 1-in. tall lettering will be used on the cover.

Airvac recommends that concrete collars be used for all 2-piece valve pits located in traffic areas. Airvac further recommends that concrete collars be used for all 1-piece Airvac valve pits regardless of their location (see page 6-12 for discussion on anti-buoyancy of 1-piece pits).

The actual design of the concrete collar is the responsibility of the Design Engineer. In addition, the Design Engineer must clearly define "traffic areas" on their construction drawings and/or specifications.

The various valve pit dimensions shown on Airvac's standard details are based on a ring thickness of ½ inch. At least one casting vendor offers a "mid-flange" style ring which will increase the overall depth of the valve pit as well as the depth to the invert of the gravity stub-out by 1-½ inches. The Engineer's specifications and standard detail drawings must note this difference.

Valve pit covers-pick holes & seals

Two types of lids are available for use on the Airvac valve pit. Either type can be used on any of the Airvac pits; however, the most common use is shown below:

- Covers for the 1-piece pit typically have a concealed pick hole and elastomer seals

- Covers for the 2-piece pit typically have an open pick hole and no elastomer seals.

For consistency purposes, when a project has both valve pit types, it is recommended that the cover with the concealed pick hole and elastomer seals be used.

Riser rings

Riser rings in either 2-inch or 3-inch heights are available for use on any Airvac valve pit if needed for final grade adjustment.

C. VALVE PIT COMPONENTS: 1-PIECE PITS

Figure 6-6 shows the 6.5-ft deep Airvac 1-piece PE valve pit assembly.

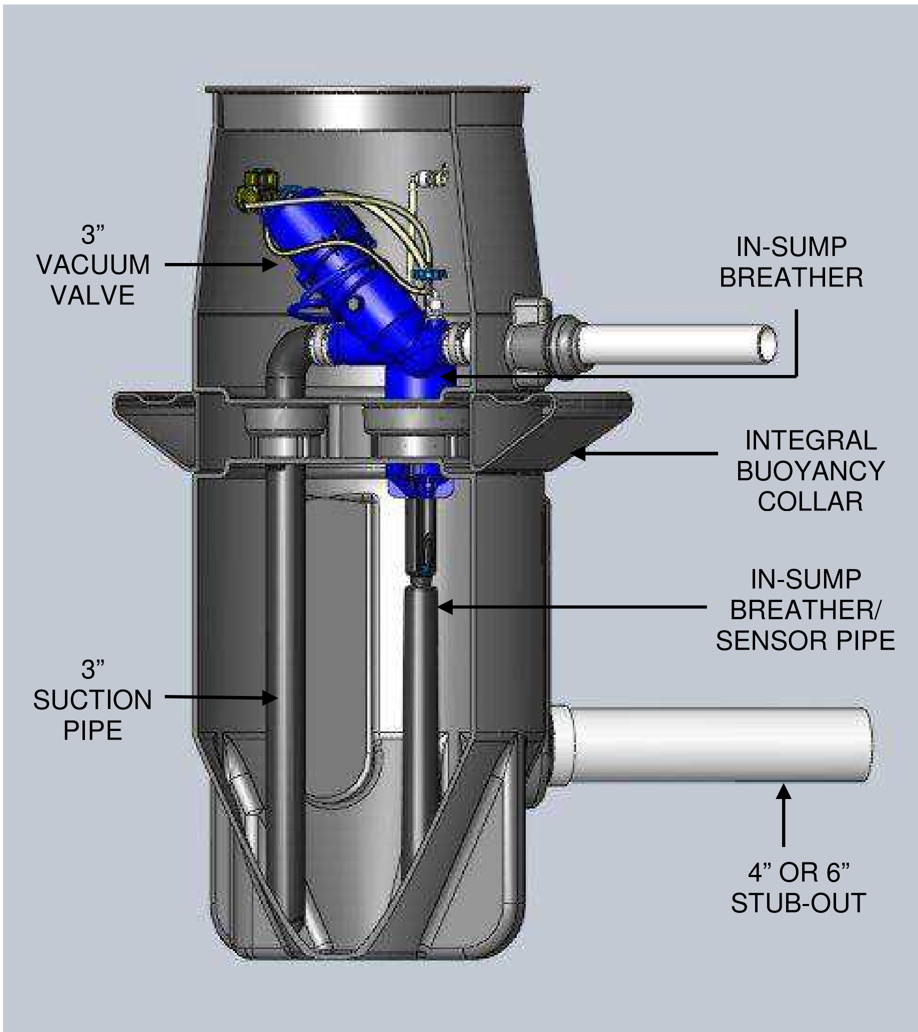


FIGURE 6-6: 1-PIECE VALVE PIT COMPONENTS

1-Piece Pit
The 1-piece pit is manufactured by the rotational molding process using PE with an integral upper valve chamber, lower collection sump and anti-buoyancy collar. The wall thickness of the entire unit is ½ inch.

The upper chamber houses the vacuum valve, controller and in-sump breather with a 36-inch inside diameter at the bottom and is conically shaped to allow fitting a 26 ¾-inch frame with a 23 ½-inch diameter cast iron cover. The upper chamber includes a 3-inch vacuum service lateral pipe support with rubber o-ring seal to insure proper pipe alignment with the valve/suction pipe. Both the 5-ft and 6.5-ft deep pit have an upper chamber depth of 30-inches. A 12-inch extension piece is available if a 7.5-ft deep pit is required.

The lower chamber contains 4 stabilizing embosses to support the valve pit and is designed to allow up to (4) houses to be connected with either 4-inch or 6-inch pressure rated Sch 40, SDR 21 or SDR 26 PVC pipe. Elastomer connections are used for the entry of the building sewer. Holes for the building sewers are field cut at the position directed by the engineer. The 5-ft deep pit has a lower sump depth of 30-inch and a capacity of 57 gallons, while the 6.5-ft deep pit has a lower sump depth of 48-inch and a capacity of 115 gal.

Sensor Pipe/In-Sump Breather
The 3-inch sensor pipe and sump-breather are combined into one unit with a twist lock mechanism to mate with the hole connecting the upper and lower chambers. A rubber seal prevents water infiltration into the lower sump.

Suction Pipe
The 3-inch suction pipe is made of PE and also has a twist lock mechanism to mate with the hole connecting the upper and lower chambers. A rubber seal prevents water infiltration into the lower sump.

Integral Anti-Buoyancy Collars
The Airvac 1-piece valve pit has a factory installed integral PE anti-buoyancy collar that is sufficient in most cases; however, in certain circumstance additional ballast is needed. This can be achieved by installing a concrete collar of sufficient weight around the valve pit as shown below:

Concrete Collars - Minimum weight of concrete required (lbs)				
Pit Type	**Groundwater @ surface**	**Groundwater @ 1 ft depth**	**Groundwater @ 2 ft depth**	**Groundwater @ >2 ft depth**
VP3030P1	200	0	0	0
VP4830P1	800	400	0	0
VP4842P1	1100	600	200	0

D. VALVE PIT COMPONENTS: 2-PIECE PITS

Figure 6-7 shows the 6 ft deep Airvac PE 2-piece valve pit assembly. The 2 major pieces are the valve pit cone, and the combined sump/pit bottom.

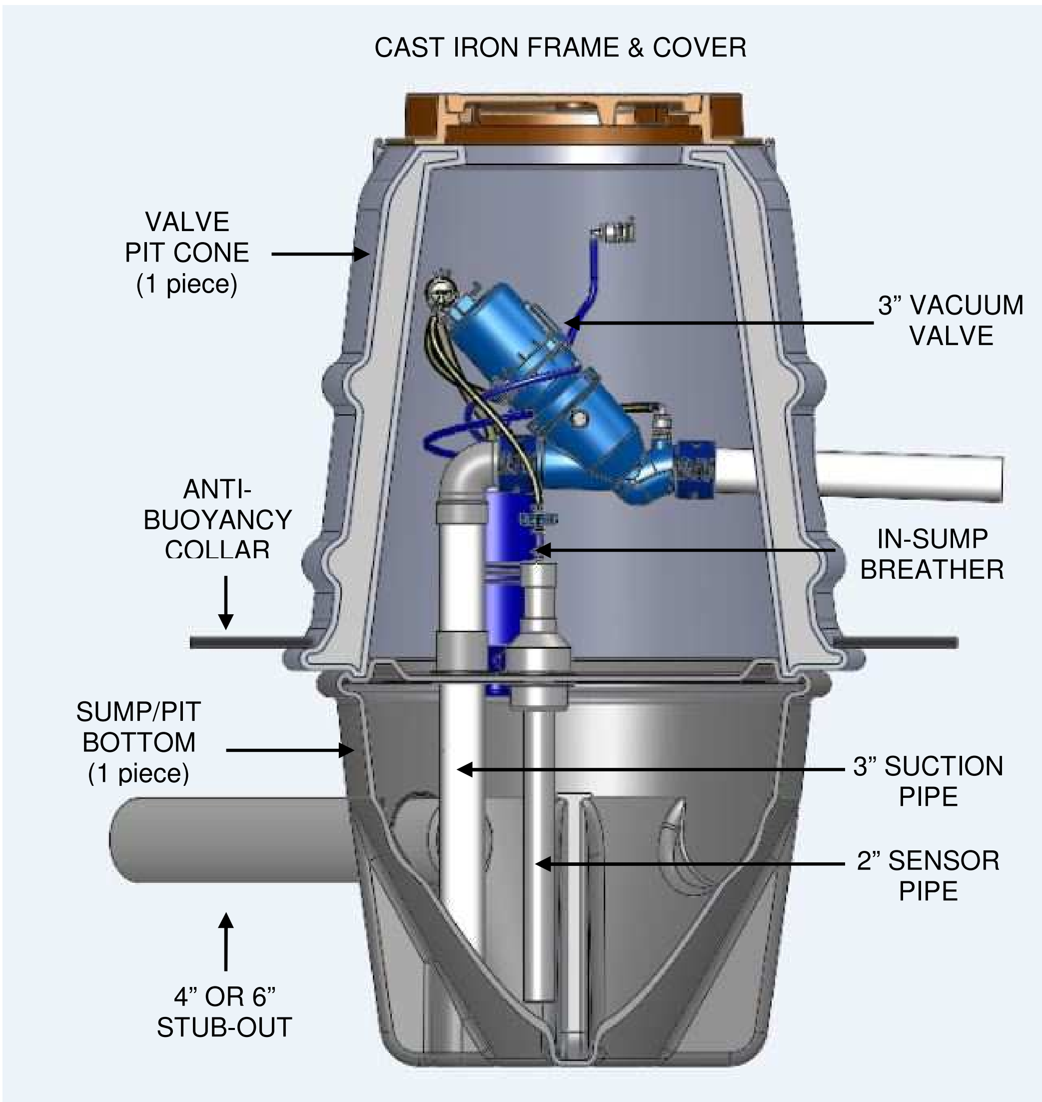


FIGURE 6-7: 2 PIECE VALVE PIT COMPONENTS

Valve Pit Cone
The upper chamber houses the vacuum valve, controller and in-sump breather and is manufactured by the rotation molding process using PE. It has a 36-inch inside diameter at the bottom and is conically shaped to allow fitting a 26 ¾"-inch frame with a 23 ½-inch diameter cast iron cover. The upper chamber includes a 3-inch vacuum service lateral pipe support with rubber O-ring seal to insure proper pipe alignment with the valve/suction pipe. The 6 ft, 8 ft and 10 ft deep pits all have an upper chamber depth of 42-inches.

Sump/Pit Bottom
The sump and pit bottom are manufactured as a single piece by the rotation molding process using PE. It is tapered with the upper rim designed to accept the valve pit cone. The sump for the 6 ft deep pit has an overall height of 30-inches with a capacity of 85 gallons. The sump for the 8 ft deep pits has an overall height of 54-inches with a capacity of 158 gallons. The sump for the 10 ft deep pits has an overall height of 78-inches with a capacity of 250 gallons.

The sump contains 4 stabilizing embosses to support the valve pit and is designed to allow up to (4) houses to be connected with either 4-inch or 6-inch pressure rated Sch 40, SDR 21 or SDR 26 PVC pipe. Elastomer connections are used for the entry of the building sewer. Holes for the building sewers are field cut at the position directed by the engineer

If desired, the valve pit cone and the sump can be welded together to make a completely sealed unit. This is done with an adhesive applied by the contractor at the jobsite; however, caution must be exercised to ensure this is not done under water.

In-Sump Breather
The in-sump breather uses atmospheric air from the 6-in. Air Terminal (or the 4-in. air-intake on the building sewer) which is connected to the sump. The in-sump breather is designed to protect the controller from unwanted liquid during system shut-downs and restarts. It also prevents sump pressure from forcing the valve to open during low vacuum conditions and provides positive sump venting regardless of traps in the gravity building sewer.

Suction and Sensor Pipes
Both the 3-in. suction pipe and the 2-in. sensor pipe are Schedule 40 PVC and are installed through grommets in the pit bottom.

Anti-Buoyancy Collars

Airvac provides a 1" thick PE anti-buoyancy collar with each 2-piece pit (see Fig 6-8). These collars fit around the tapered valve pit and rely on soil burden to keep the pit from floating.

Unlike the integral anti-buoyancy collar of the 1-piece pit, the PE anti-buoyancy collar used on the 2-piece pits is sufficient to prevent flotation regardless of the ground water level.

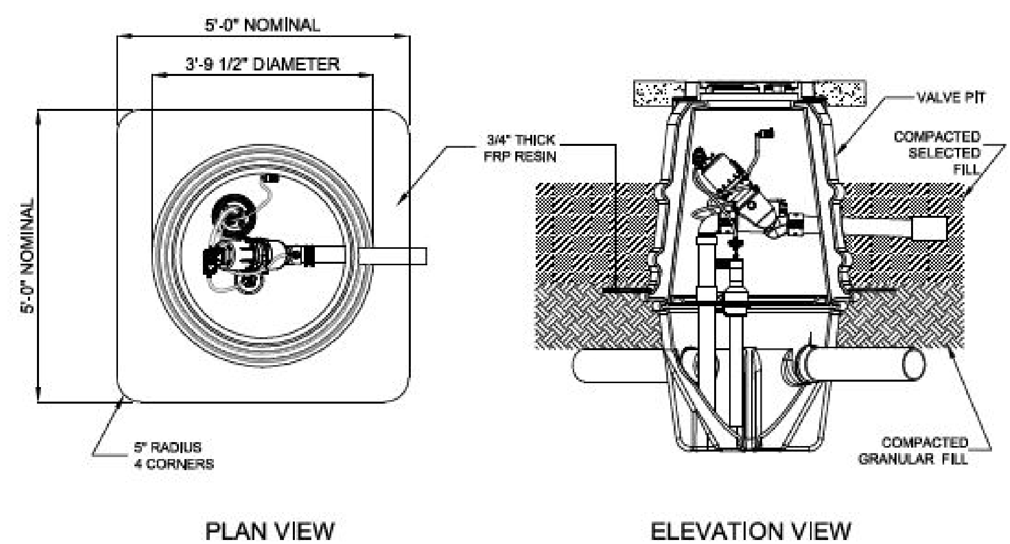


FIGURE 6-8: AIRVAC ANTI-BUOYANCY COLLAR

Anti-buoyancy collars consisting of mass concrete rings are not recommended.

E. VALVE PIT COMPONENTS: 2-PIECE COLD WEATHER PITS

Figure 6-9 shows the 6 ft deep Airvac PE 2-piece cold weather valve pit assembly. This is a modification of the standard 2-piece valve pit where the cone top includes a double wall with an imbedded layer of insulation and an insulated lid insert under the standard cover. As a further precaution, Airvac recommends not locating valve pits in roads and berms in cold weather climates.

All other pit components (sump, pit bottom, sensor pipe, in-sump breather, suction pipe, and anti-buoyancy collar) are identical to those included with the standard 2-piece valve pit.

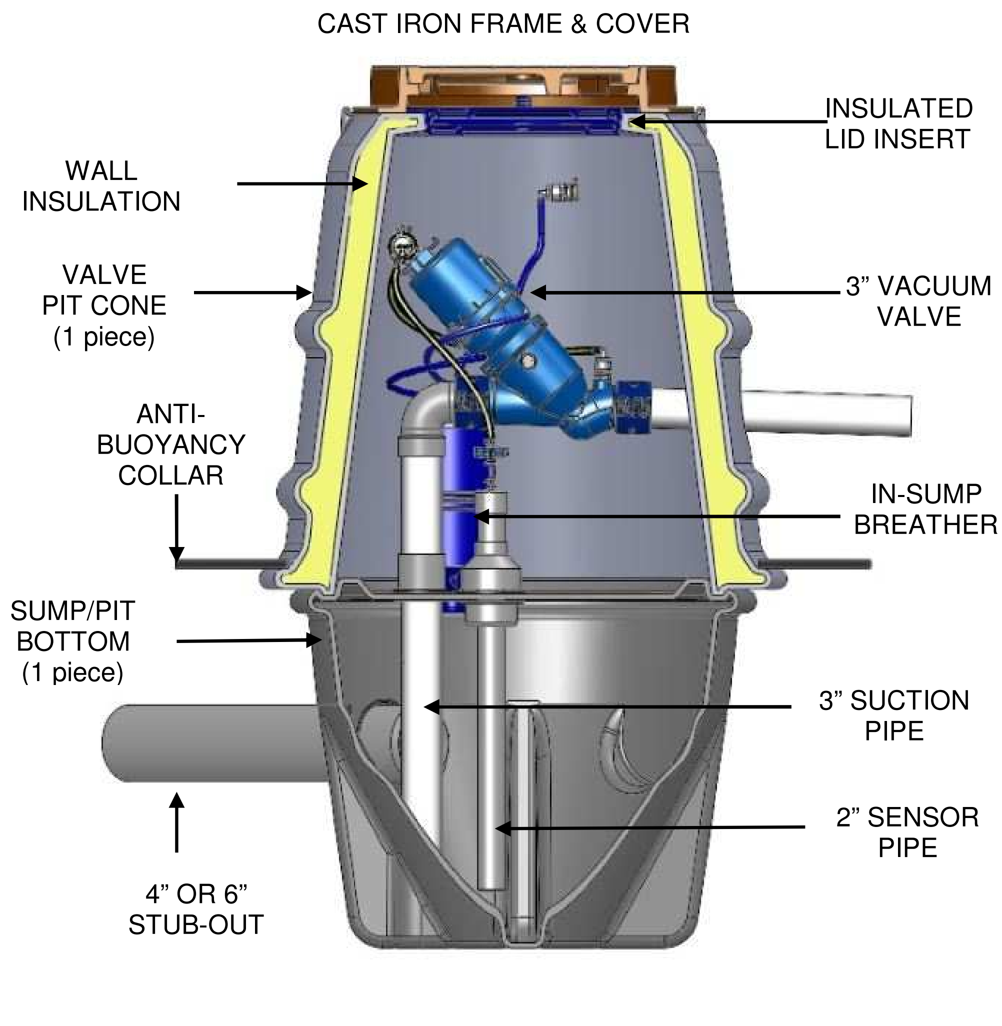


FIGURE 6-9: 2 PIECE COLD WEATHER VALVE PIT COMPONENTS

F. BUILDING SEWER (House to Pit)

Building Sewer
The term building sewer refers to the gravity pipe extending from a building to the valve pit and typically includes pipe in both private property as well as public R-O-W. The building sewer consists of 2 parts: the 4 or 6-inch gravity house lateral exiting the building and the 4 or 6-inch stub-out pipe from the valve pit.

For residential service, the building sewer should be 4-inch and slope continuously downward at a rate of not less than 0.25-in/ft (2-percent grade). Consult local codes for line size requirements for commercial users.

Airvac recommends that pressure rated pipe be used for the building sewer for two reasons. First, the pipe OD must match the valve pit inlet grommet to prevent the entrance of I/I in to the valve pit sump. Second, the building sewer may be exposed to high vacuum at times. Under normal conditions, these vacuum levels would be low (5-10-in. Hg) and would occur for just the short valve cycle duration. However, should the air intake become blocked and the vacuum valve fail in the open position at the same time, the building sewer could see full system vacuum of 20-in. Hg for an extended period of time

Table 6-2 shows Airvac's recommendations. These recommendations assume that the pipe is also in compliance with all applicable codes.

Source of atmospheric air
There are two options for providing the source of atmospheric air necessary for liquid transport (see pages 6-20 thru 6-23):

- Use a 6-inch Air Terminal at each valve pit (recommended)
- Use a 4-inch Air Intake at each house (optional)

With the Air Terminal, the installation details are included in the design documents. It is installed by the contractor during the construction phase and becomes the Utility's responsibility to maintain. With the air-intake, installation typically is by the homeowner's plumbing contractor during the home hookup phase and it then becomes the homeowner's responsibility to maintain.

The house vent may not be used in place of the Air Terminal or Air Intake as its location could result in the house plumbing traps being evacuated during a valve cycle. For this reason, the source of atmospheric air must be located downstream of the last house plumbing trap. NOTE: *The use of a check valve within an air intake mechanism itself is not recommended as this may result in problems with the traps inside the house. In addition, bellies and/or the excessive use of fittings in the homeowner's gravity piping could result in inadequate venting requiring an additional Air Terminal or air intake be used.*

Table 6-2

Recommended Pipe Types for Stub-Outs and Building Sewers

		Type	Rated Press. (psi)	O.D (in).	I.D. (in)	Wall thickness (in.)	Weight per 100 ft (lbs)	ASTM
RECOMMENDED For Stub-out and Building Sewer	**Pressure**							
	Sch 40	DWV	220	4.500	4.026	0.237	210.2	D1784 D1785 D2466
	SDR 21	DWV	200	4.500	4.046	0.214	188.6	D2241 D2464
	SDR 26	DWV	160	4.500	4.145	0.173	154.0	D2241 D2464
DO NOT USE For Stub-out **NOT PREFERRED** For Building Sewer (But OK if Stub-out uses recommended pipe)	**Non-Pressure**							
	Sch 40 (solid wall)	DWV	0	4.500	4.026	0.237	200.0	D1784 D1785 D2665
	Sch 40 (foam core)	DWV	0	4.500	4.026	0.237	146.0	F 891 D1784 D4396 D2665
DO NOT USE For Stub-out or Building Sewers	**Non-Pressure**							
	SDR 26	S&D	0	4.215	3.891	0.162	140.0	D4396 D3034
	SDR 35 (solid wall)	S&D	0	4.215	3.965	0.125	113.0	D2729 D3034 F 679
	SDR 35 (foam core)	S&D	0	4.215	3.965	0.125		F 891

SDR: Standard Dimension Ratio = OD/wall thickness
S&D: Sewer and Drain
DWV: Drain, Waste & Vent
Stub-out: Pipe from the valve pit to property line (installed by system contractor)
Bld'g sewer: Pipe from stub-out to air-intake (installed by homeowner plumbing contractor)

NOTE: Airvac recommends that pressure rated fittings also be used for the stub-out pipe portion of the building sewer that is in the public right-of-way.

6-inch Air-Terminal (AT) - recommended

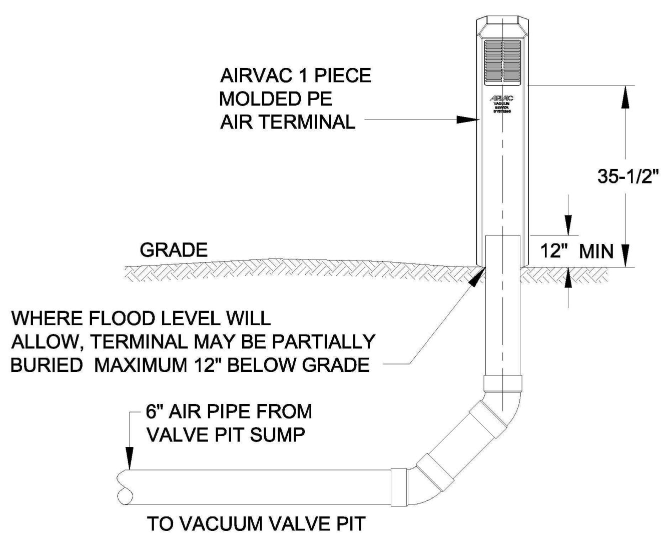
The 6-inch Air Terminal (AT) consists of a molded housing made by Airvac that is placed on 6-inch piping connected directly to a valve pit sump as shown in Fig 6-10. The Air Terminal was designed to look like other utility boxes/structures typically seen in rights-of-way. It has an access door and is available in 3 colors: sandstone (recommended), utility green, & gray granite.

In-house testing indicates that using the 6-inch Air Terminal at each valve pit results in a much more effective method of air induction than using the optional design that utilizes 4-inch air intakes at each house. For optimum results, Airvac recommends the following guidelines be followed:

- The maximum length of 6-inch pipe from valve pit to the Air Terminal is 40 feet and should not contain more than three (3) - 45-degree bends. No 90-degree bends are to be used. For every fitting over 3 that is installed in the piping between the valve pit and Air Terminal, decrease the maximum length by 5 feet per fitting. For example, if 6 fittings are used, the maximum length is reduced to 25 feet.

- The Air Terminal must be at least 10 feet closer to the pit than the length of the gravity piping from the house to the pit. For example, if the gravity piping from the house to the valve pit is 30 feet, the Air Terminal must be no farther than 20 feet from the valve pit.

- The building sewer from the house to the valve pit may be 4 or 6-inch. For optimum results, the building sewer should be connected directly to the valve pit sump and not combined with the Air Terminal piping.



(1) – 6-inch Air Terminal is required for <u>every valve pit</u>

FIGURE 6-10: 6-INCH AIR-TERMINAL (Recommended)

Advantages of the 6-inch Air Terminal

Advantages of using the 6-inch Air Terminal at each valve pit compared to using a 4-inch air intake at each house include:

1) The Air Terminal’s use eliminates the need for the unsightly 4-inch air-intake in the homeowner’s gravity piping which is located either next to the house or in the middle of the yard.

2) Considerably reduces the possibility of vacuum emptying home plumbing traps and eliminates any adverse effects on the valve operation associated with improper gravity lateral installations (improper fall, belly in piping).

3) Allows the valve pit to be put into service before any home gravity laterals are installed (see discussion on page 6-24). This also relieves the fear of possible pit implosion that could occur when a valve is installed without the homeowner’s 4” air-intake in place.

4) Provides a mounting point for future options such as a cycle counter, valve monitoring equipment, or even the valve controller itself.

5) Prevents the operating Utility from becoming involved with problem diagnosis relating to improper gravity lateral installations. If the valve pit functions properly, any other problem is the homeowner’s responsibility.

6) Shifts the responsibility of the installation and maintenance of a key system component from the homeowner to the operating entity and provides the operator access without entering the customer’s property.

4-inch Air Intake – optional

As an option, a 4-inch air intake on each house building sewer can be used. This consists of 4-inch PVC pipe, fittings and a screen as shown in Figure 6-11. Most plumbing-codes require the air intake to be located against a permanent structure, such as the house or a wall. For optimum results, Airvac recommends the following guidelines be followed:

1 house connected to valve pit using 1 – 4-inch air intake

- The maximum length of 4-inch pipe from the valve pit to the air-intake is 60 feet and should contain no more that 2 - 45-degree bends. No 90-degree bends should be used. For every fitting over 2 that is installed in the piping between the valve pit and air-intake, decrease the maximum length by 5 feet per fitting. For example, if 6 fittings are used, the maximum length is reduced to 40 feet.

- A 4-inch air intake must not have any fittings from the wye upwards from the gravity line to air intake, other than those shown in Fig 6-11. No 90-degree bends or tee fittings should be used.

Multiple houses connected to valve pit each with a 4-inch air-intake

- The maximum length of 4-inch pipe from the valve pit to the air-intake is 100 feet and should contain no more that 2 - 45-degree bends. No 90-degree bends should be used. For every fitting over 2 that is installed in the piping between the valve pit and air-intake, decrease the maximum length by 5 feet per fitting. For example, if 6 fittings are used, the maximum length is reduced to 80 feet.

- A 4-inch air intake must not have any fittings from the wye upwards from the gravity line to air intake, other than those shown in Fig 6-11. No 90-degree bends or tee fittings should be used.

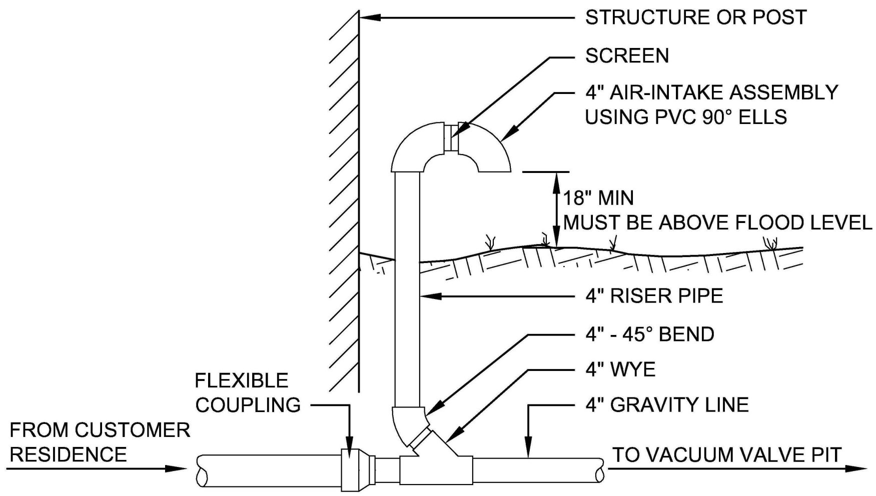
Option: Upsize 4-inch air-intake to 6-inch air-intake

As an option, both the building sewer and the air-intake can be up-sized to 6-inches. The following guidelines should be followed, either when 1 house or multiple houses are connected to a valve pit.

- The maximum length of 6-inch pipe from the valve pit to the air-intake is 160 feet and should contain no more that 3 - 45-degree bends. No 90-degree bends should be used. For every fitting over 3 that is installed in the piping between the valve pit and air-intake, decrease the maximum length by 5 feet per fitting. For example, if 6 fittings are used, the maximum length is reduced to 145 feet.

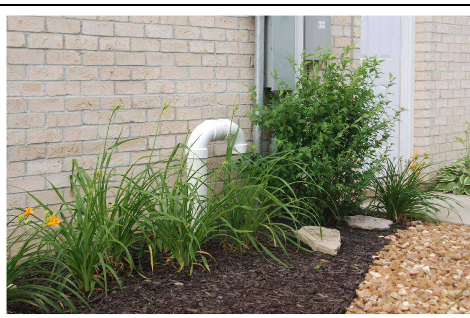
- A 6-inch wye must be used. No 90-degree bends or tee fittings should be used.

Airvac also recommends that, if possible, the air-intake be located at least 10 feet from the nearest plumbing trap in all cases involving a 4-inch or 6-inch air intake. This recommendation is offered as an additional precaution against possible adverse effects on the house plumbing traps, however; if the previously noted requirements on page 6-22 are followed, the likelihood of any negative effects are minimal.



(1) – 4-inch air intake is required <u>for every house</u>

FIGURE 6-11: 4-INCH AIR INTAKE (Optional)



AIRVAC is not responsible for any adverse effects that improper venting may cause to connected homes. The guidelines presented have been proven by testing performed on actual plumbing configurations used in conjunction with vacuum sewer systems. While not as effective as the 6-inch Air Terminal, the 4-inch air intakes have been used for many years and in most cases performed adequately.

Proper Time to Install the Vacuum Valve if the 6-inch Air Terminal is NOT used

If the recommended 6-inch Air Terminal is not used, the Airvac vacuum valve should be installed ***only after the homeowner has connected*** the building sewer to the stub-out at the valve pit. (See Figures 6-12 & 6-13) ***and the 4-inch air intake is in place***. The normal sequence of events is as follows:

- Contractor installs lines and pits
- Contractor conducts final 4-hour test on lines & station
- Contractor flushes vacuum mains
- The system is accepted by the operating entity
- Homeowner's plumber installs building sewer and the 4-inch air intake
- Operating entity installs the vacuum valve

Potential Problems if Valve is installed During Construction

The desire to have a complete system has led some design engineers to require the system installation Contractor to install the Airvac vacuum valve during the construction period. Airvac does not recommend this procedure as this can result in some very serious problems as described below:

Pit collapse/implosion: Cycling the Airvac valve without the homeowner's lateral and 4-inch air intake installed can cause the bottom sump to implode. This would require the pit to be re-excavated and replaced. This not only is costly, but finger-pointing on who is to blame will surely ensue. Cycling of the valve could occur if extraneous water could enter the sump through a stub-out that was not capped or may even happen if just a miniscule amount of air leaked through the vacuum valve seat.

Homeowner may illegally hook-up early: Knowing that a complete system is available, the homeowner could connect to the valve pit without the Owner's knowledge. This action would preclude the Owner from doing the normal inspection of the homeowner's gravity lateral, air intake, etc. Again, this could lead to some serious problems such as I&I, water in the controller, etc.

Valve may be improperly installed: It is conceivable that the Contractor may connect hoses to the wrong port, fail to tighten all hose clamps, fail to adjust the controller timing properly, etc. Any of these could severely affect the operation of the system.

Valve timing may be improper (timing is site specific): The timing of the valves is a major concern. Each valve needs to be adjusted differently according to its location within the system. Airvac believes that it is expecting too much for the Contractor to know how to balance the system by properly timing each valve. The Contractor cannot be expected to be a vacuum expert. The valve should be properly installed and timed by someone who has been trained to do so, such as the system operator or Airvac personnel.

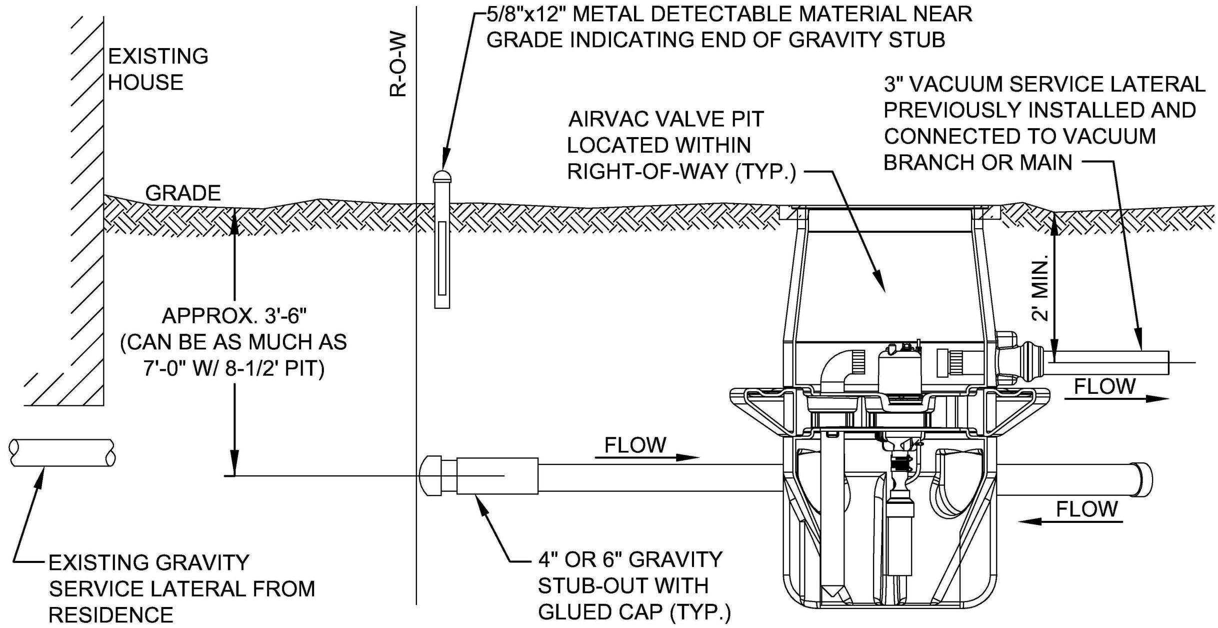


FIGURE 6-12: VALVE PIT INSTALLATION PRIOR TO HOME HOOK-UP

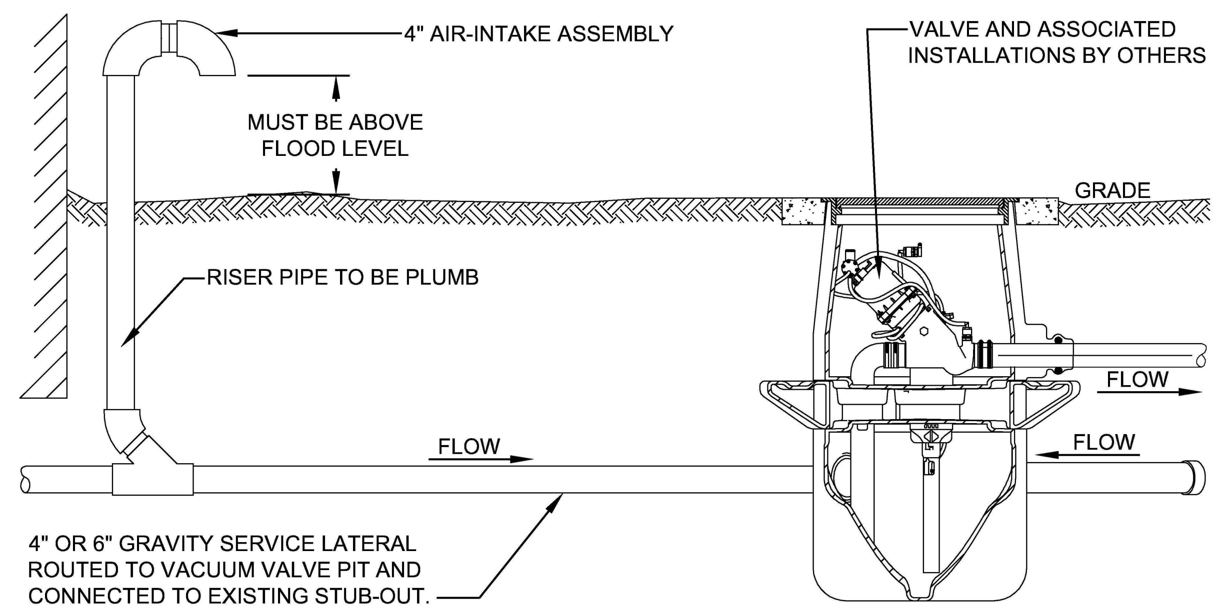


FIGURE 6-13: VALVE PIT INSTALLATION AFTER HOME HOOK-UP (WHEN 4-INCH AIR INTAKE IS USED)

Backwater Valves
Some entities prefer the use of backwater valves on the homeowner's building sewer to provide sewage backup protection for houses that share a valve pit. This is especially true when the houses are at different elevations.

For the typical "normally closed" type backwater valve, location of the backwater valve is critical. If not installed between the home and the gravity air intake pipe, the Airvac valve will not operate.

Airvac recommends backwater valves that are designed to be "normally opened". Positioning is not an issue for this type of valve and they have proven to have superior performance when used in a vacuum system. They are currently available only in the 4-inch size.

In any case, Airvac should be consulted before such a device is installed.

Grease Traps
State and local codes typically require grease traps for restaurants, hotels or any other establishment that serves meals. These are simple devices, usually placed in the kitchen floor that are designed to provide retention time for grease to cool and solidify so that it can be removed before it enters the sewer system.

Grease that can enter and solidify in a valve pit can cause problems with the operation of the valve. The most common problem would be grease that enters the sensor pipe and later accumulates between the surge suppressor and controller. Grease in this area would not allow the free flow of air necessary for valve closure and the valve would remain open.

In general, grease is rarely a problem with the standard Airvac valve pit. It is more likely to be a problem in a buffer tanks as these are used to serve the type of commercial establishments where grease can be a problem.

Airvac recommends that the sewer authority require all customers to follow codes regarding the installation of grease traps.

Connection via a Pump
Airvac does not recommend connecting a grinder pump or lift station directly to an Airvac valve pit. Instead, a transitional manhole should be used as an interface between pressure and vacuum. As an option, a buffer tank can be used for this transition.

If there is no other practical way to serve a customer other than connecting a pump directly to an Airvac valve pit, contact Airvac's Engineering Department for guidance.

H. DO'S AND DON'TS

Table 6-3

Do's and Don'ts: Valve Pits

DON'T DO THIS:	DO THIS:
Use 1-piece valve pits in cold climates	Use 2-piece Cold Weather pits
Connect more than 4 homes to a single valve pit	Use a 2:1 ratio as a standard and carefully analyze where service to 3 or 4 homes is feasible
Exceed a peak flow rate of 3 gpm for a single valve pit	Limit peak flow to 3 gpm for a single valve pit Use buffer tanks for higher flows
Allow infiltration in the homeowner's building sewer	Ensure building sewer meets specification and is inspected by the local authority
Connect any home or other establishments with storm systems attached	Ensure no downspouts, sump pumps, cisterns or other storm water receptacle are connected
Use non-pressure pipe & fittings for stub-outs or building sewers	Use pressure rated pipe & fittings for stub-outs and building sewers as shown on Table 6-2
Allow bellies in the building sewer which could fill with liquid and block off air	Inspect the building sewer prior to pipe burial to ensure no bellies exist
Combine sewage and air by manifolding a building sewer to the 6-inch Air-Terminal	Use the 6-inch Air-Terminal as an "air-only" device
Allow installation of the 3-inch interface valve until either the 6-inch Air Terminal or the 4"-inch air intake is in place	Install 6-inch Air terminal or the 4-inch air intake prior to the valve installation
Connect a grinder pump directly to an Airvac valve pit	Use a transitional manhole as an interface between pressure & vacuum

CHAPTER 7
BUFFER TANKS

A. GENERAL DESCRIPTION

Buffer tanks are typically used for schools, apartments, nursing homes, and other large-volume water users. Buffer tanks function in a similar manner to the standard Airvac valve pit but have additional storage capacity in the sump area to allow for a large, instantaneous flow inputs to be temporarily stored while the vacuum valve(s) evacuate the sump.

B. IMPACT OF LARGE FLOW ON VACUUM VALVE CAPACITY

The Airvac 3-inch valve can admit 30 gpm of liquid, ***assuming sufficient vacuum levels exist at the valve location*.** This capacity is achieved when the valve cycles 3 times in a minute, with each cycle discharging 10 gallons as described in the following paragraph.

The length of one complete valve cycle is about 6-8 seconds, consisting of 2-3 seconds for the liquid, followed by 4-5 seconds of air. During this time, vacuum levels at the valve location temporarily drop as energy is used to admit the sewage into the main line. The valve rests before the next cycle begins, which occurs when another 10 gallons accumulates in the sump. Vacuum recovery occurs during the valve-closed time as the vacuum level in the main is restored. Typically, a rest period of 10-15 seconds is needed to allow vacuum to be restored to normal levels.

When vacuum levels decrease there is a corresponding decrease in the valve capacity. This is due to the lower pressure differential that exists which results in less available energy and hence slower evacuation times.

A low vacuum condition can occur when a larger than usual amount of flow enters the main, followed by a relatively small amount of air, resulting in a low air-to-liquid ratio. This could occur, for example, at a buffer tank where high discharge rates are common and where repeated firing of the valve over short periods of time may not allow sufficient vacuum recovery. The net result would be progressively decreasing pressure differentials and lower evacuation rates.

The net result is that large flows and high valve discharge capacity are typically not compatible. Buffer tanks require high discharge rates; however, this higher rate may result in water-logging which would result in a lower evacuation capacity of the ***next*** valve cycle.

C. LIMITATION ON USE

Efficient flow within a vacuum system relies on partial liquid and partial air inputs at controlled rates. This is normally accomplished by uniform distribution of valve pits through a service area with each valve pit attached to no more than four (4) homes. This allows relatively small liquid flow followed by a volume of air for propulsion of liquid. In this manner, a uniform system air-to-liquid ratio is maintained thereby maximizing available vacuum throughout the system.

By contrast, buffer tanks with valves that cycle frequently can sometimes contribute larger volumes of the liquid, but with the same amount of air. This can lead to irregular air to liquid ratios, inefficient vacuum pump performance and sluggish system operation. For these reasons, buffer tanks should only be utilized under the following conditions:

- Buffer tanks should not be used where individual valve pits could otherwise be utilized.
- Buffer tanks should not be used to accept flow from a gravity system serving large group of houses (e.g.: connecting 20 houses on a street by gravity with the flow going to a buffer tank).
- Buffer tanks should be limited to users where connection at only one or two locations is possible (e.g.: a commercial user where all flow from the building is manifolded into 1 or 2 sewer lines).
- A system with nothing but high-flow inputs is not recommended, although it is possible to have a *limited* amount of high-flow inputs (buffer tanks) into a vacuum system. See the design rules in Section E of this chapter.

Much depends on the location of the buffer tank, the length of travel to the vacuum station, the amount of static loss in the system, and the proximity of other buffer tanks. In general, the closer to the vacuum station, the fewer lifts to overcome and the fewer other buffer tanks connected to the same vacuum main, the less likely it is that the buffer tank will have an adverse effect on the system operation.

D. BUFFER TANK SIZING

Considering the previous discussion, a lower peak flow evacuation rate of 15 gpm is recommended for buffer tank sizing. This lower rate assists proper vacuum recovery and provides a safety factor of sorts.

Table 7-1 shows the recommended design capacities as well as the maximum allowable design flow rates to use for buffer tanks.

Table 7-1

Recommended Design Flow Rates
For Buffer Tanks

Buffer Tank Type	Recommended Design Peak Flow (gpm) **(as a general rule)**	Absolute Maximum Peak Flow (gpm) **(case by case) ***
Single Buffer tank	3.1 - 15.0 gpm	30 gpm
Dual Buffer tank	15.1 - 30.0 gpm	60 gpm
Consult Airvac	> 30.0 gpm	> 60 gpm

For flow inputs greater than 30 gpm, please consult Airvac. Assuming system hydraulics allows, it may be possible to use a splitter manhole, which will evenly split and divert the flow to two or more dual valve buffer tanks (see Figure 7-4).

NOTE: *Depending on static and friction loss, the overall amount of peak flow entering the system through buffer tanks and the exact location of the buffer tank, it may be possible to size a buffer tank with the upper limits shown in the Absolute Maximum Peak Flow column. Consult Airvac's Engineering Department for guidance and approval.*

E. DESIGN RULES

Vacuum main sizes
To provide sufficient vacuum recovery time, Airvac recommends the following vacuum main sizes be used with buffer tanks:

- Single buffer tanks are to be connected to a 6-inch or larger vacuum main.
- Dual buffer tanks are to be connected to an 8-inch or larger vacuum main.

Consult Airvac's Engineering Department for guidance and approval if deviations from the above recommendations are desired.

Maximum flow contributed by buffer tanks
To minimize the possibility of system water-logging, Airvac recommends the use of buffer tanks be limited as follows:

- **25% rule:** No more than 25% of the total peak flow of the entire system should enter through buffer tanks.
- **50% rule:** No more than 50% of the total peak flow of a single vacuum main (i.e. – single flow path) should enter through buffer tanks.
- **On a case by case basis:** Depending on static and friction loss and the exact location of the buffer tank, it may be possible to exceed the 25% and 50% limits shown above. *Consult Airvac's Engineering Department for guidance and approval.*

Maximum flow at a single location
The positioning of a buffer tank(s) within the collection system has an impact on system hydraulics. In general, the greater the distance from the vacuum station the buffer tank is and the higher the static loss that must be overcome, the larger the negative effect becomes on the overall transport capabilities of the system. While there are no hard and fast rules regarding this issue, consult Airvac's Engineering Department for guidance on the placement of buffer tanks.

Buffer tanks fed by a pump
When a lift station or grinder pump discharges to a buffer tank, the conventional peak flow figures for the customers served by the pump should not be used. Rather, ***the rated discharge capacity of the pump should be used*** to size the buffer tank. Consult Airvac for guidance on input values for friction loss.

F. TYPES OF BUFFER TANKS

Buffer tanks are available in either concrete or fiberglass. There are pros and cons of each and the engineer should consider these when selecting a buffer tank type.

Table 7-2

Fiberglass Buffer Tanks

PROS	CONS
No confined spaces	More expensive than concrete
Operator not exposed to raw sewage	Higher freight cost
Corrosion not an issue	Less usable storage than concrete
Valve mounting hardware not required	Traffic cover is large & heavy
Vacuum line & gravity stub-out molded in	
Available in standard depths (6' thru10')	
Longer life than concrete	

Table 7-3

Concrete Buffer Tanks

PROS	CONS
Less expensive than fiberglass	Operator is exposed to raw sewage
Can be made locally (less freight)	More field assembly required
Can be used anywhere (traffic or non-traffic)	Concrete tank and valve mounting hardware susceptible to corrosion
More usable storage than fiberglass	Possible odor and I/I problems that are common with manholes
	Entry to tank is subject to OSHA requirements

G. DESCRIPTION – FIBERGLASS BUFFER TANKS

A prefabricated buffer tank made of a composite material is available from Airvac in the following sizes:

Table 7-4

Fiberglass Buffer Tanks – Effective Storage Volume

Single Buffer Tank	Dual Buffer Tank	Overall Depth (ft)	Effective storage volume (gal)
SBT 72	DBT 72	6 ft	329
SBT 84	DBT 84	7 ft	423
SBT 96	DBT 96	8 ft	517
SBT108	DBT108	9 ft	611
SBT120	DBT120	10 ft	705

The tank outer wall is fabricated from filament wound fiberglass and includes an integral three-inch bottom flange to accept an anti-flotation ballast ring (by others). Depth shall be as indicated on the engineer's plans.

A gas tight removable sump/valve chamber divider separates an upper valve pit area from the lower sewage collection sump. The divider is factory drilled and fitted with grommets for suction pipe assemblies, sensor/clean-out assemblies, and sump breather units.

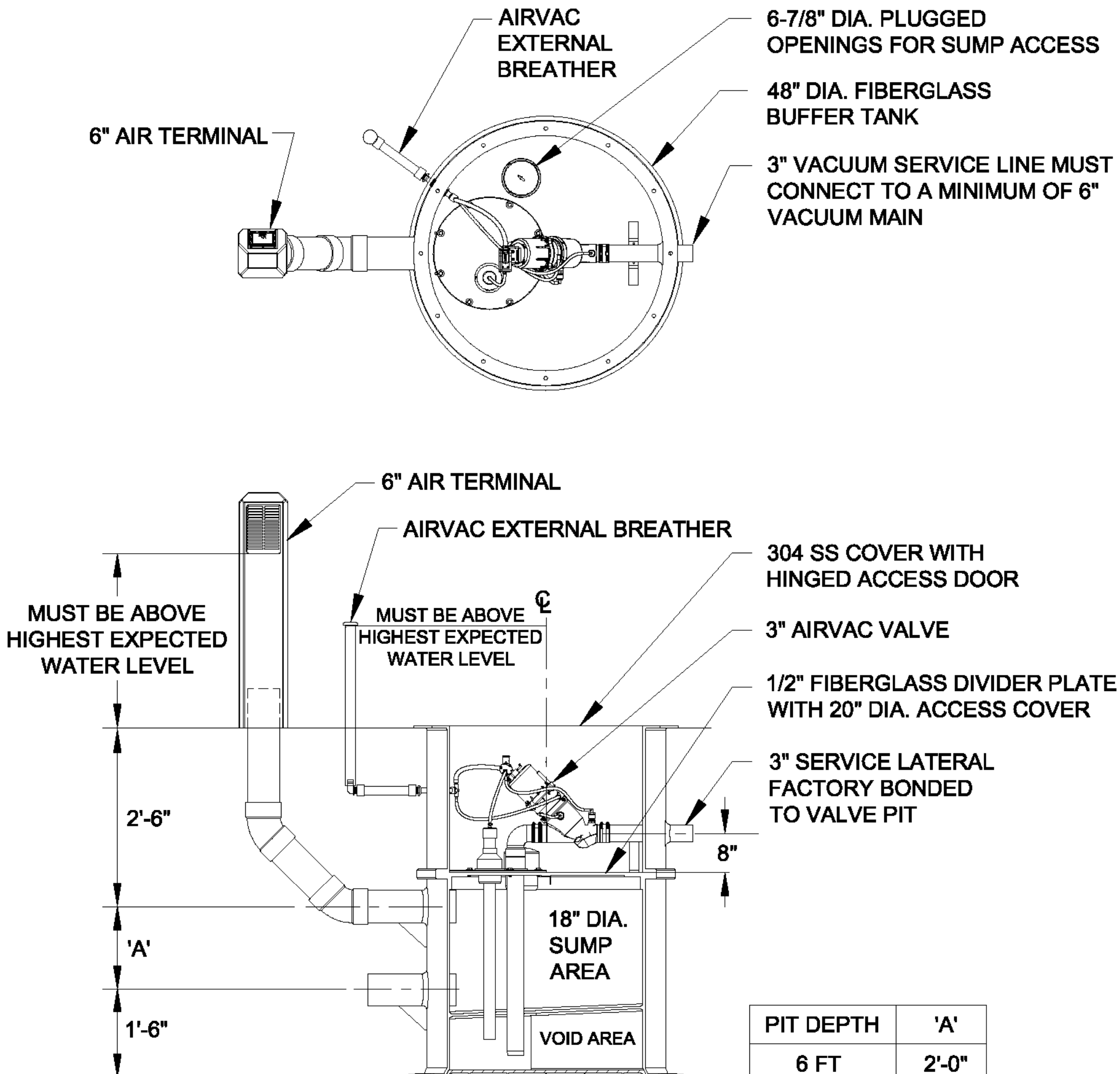
The collection sump contains an integral basin for each vacuum valve installed in the structure. Basin design is such that each valve cycle will remove approximately 10 gallons of liquid. Dual valve buffer tanks will include provisions to divide flow between the two collection sump basins.

A 3-inch Sch 40 or SDR 21 PVC service lateral, 6-ft. long, is installed through the wall of the tank and a flexible service connector assembly is provided (one of each for a SBT; 2 of each for a DBT).

A single 6-inch PVC gravity sewer pipe, 6-ft. long is installed through the tank wall for connection in the field by the contractor. Suction and sensor pipes and grommets for each pipe passing through the valve pit, valve pit bottom and sump are provided.

A 48-inch diameter 304 Stainless steel cover that includes a hinged access door with hasp for padlock is included.

Because the valve and controller are in a separate chamber above the sealed sump, entry to a fiberglass buffer tank is not subject to OSHA requirements.



PIT DEPTH	'A'
6 FT	2'-0"
7 FT	3'-0"
8 FT	4'-0"
9 FT	5'-0"
10 FT	6'-0"

FIGURE 7-1: FIBERGLASS SINGLE BUFFER TANK

H. DESCRIPTION – CONCRETE BUFFER TANKS

Concrete buffer tanks typically use standard 4-foot diameter manhole sections with a small sump formed in the lower portion of the manhole that is of the same geometry as the sump in the standard Airvac valve pit. Additional emergency sewage storage is provided by the manhole in the area above the sump.

The sump is to be 18-inches in diameter with a depth of 12-inch so that the Airvac vacuum valve operates just as it would in a regular Airvac valve pit. In no case should a buffer tank be constructed without one such sump per valve.

It is very important that all joints and connections be watertight to eliminate ground-water infiltration. Equally important is the need for a well-designed pipe support system, since these tanks are open from top to bottom. The support hardware should be of stainless steel and/or plastic.

For all buffer tanks, above ground venting of the Airvac valve must be installed to insure proper venting should the buffer tank become filled with sewage. Airvac recommends the use of its 6-inch Air Terminal for this purpose.

In areas where freezing is not an issue, Airvac also recommends remotely mounting the controller in the Air Terminal so that the operator does not have to enter the actual tank for maintenance. Finally, Airvac recommends the use of an external, flexible breather rather than the in-sump breather that is used for other valve pits.

OSHA requirements govern the entry to a concrete buffer tank. In general, the operator needs to be trained in confined space entry, must have a tripod with fall restraints and wear a safety harness. The operator must also have a gas detector and log the gas levels per the confined space requirements.

Figure 7-2 shows a typical single buffer tank arrangement. Dual valve buffer tanks may also be used for higher flows (Figure 7-3 & Figure 7-4).

NOTE: Airvac only provides the internal parts of a concrete buffer including the valve, controller, mounting hardware, external breather and Air Terminal. All other work, including the concrete manhole, is provided by the Contractor.

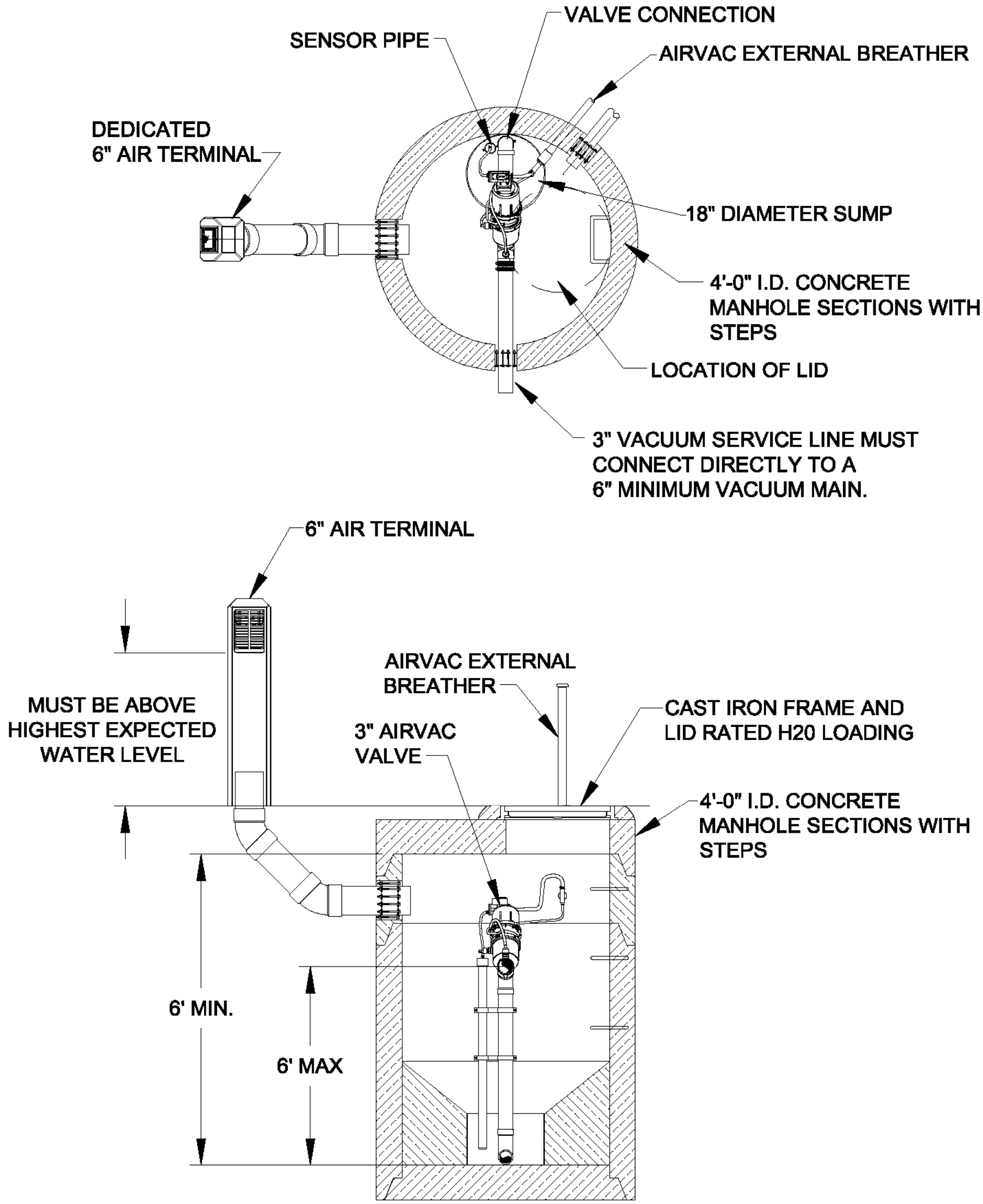


FIGURE 7-2: CONCRETE SINGLE BUFFER TANK

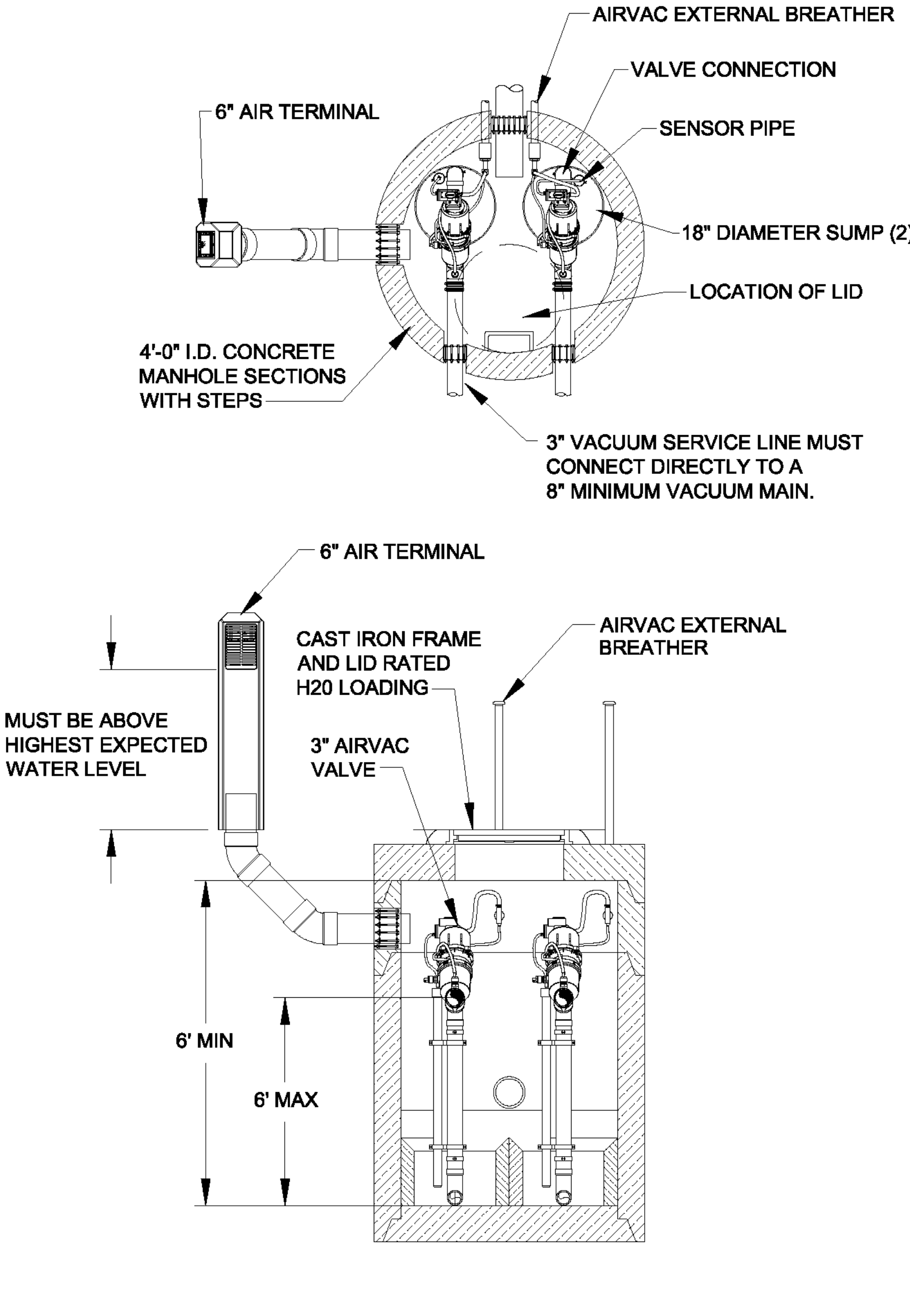


FIGURE 7-3: CONCRETE DUAL BUFFER TANK

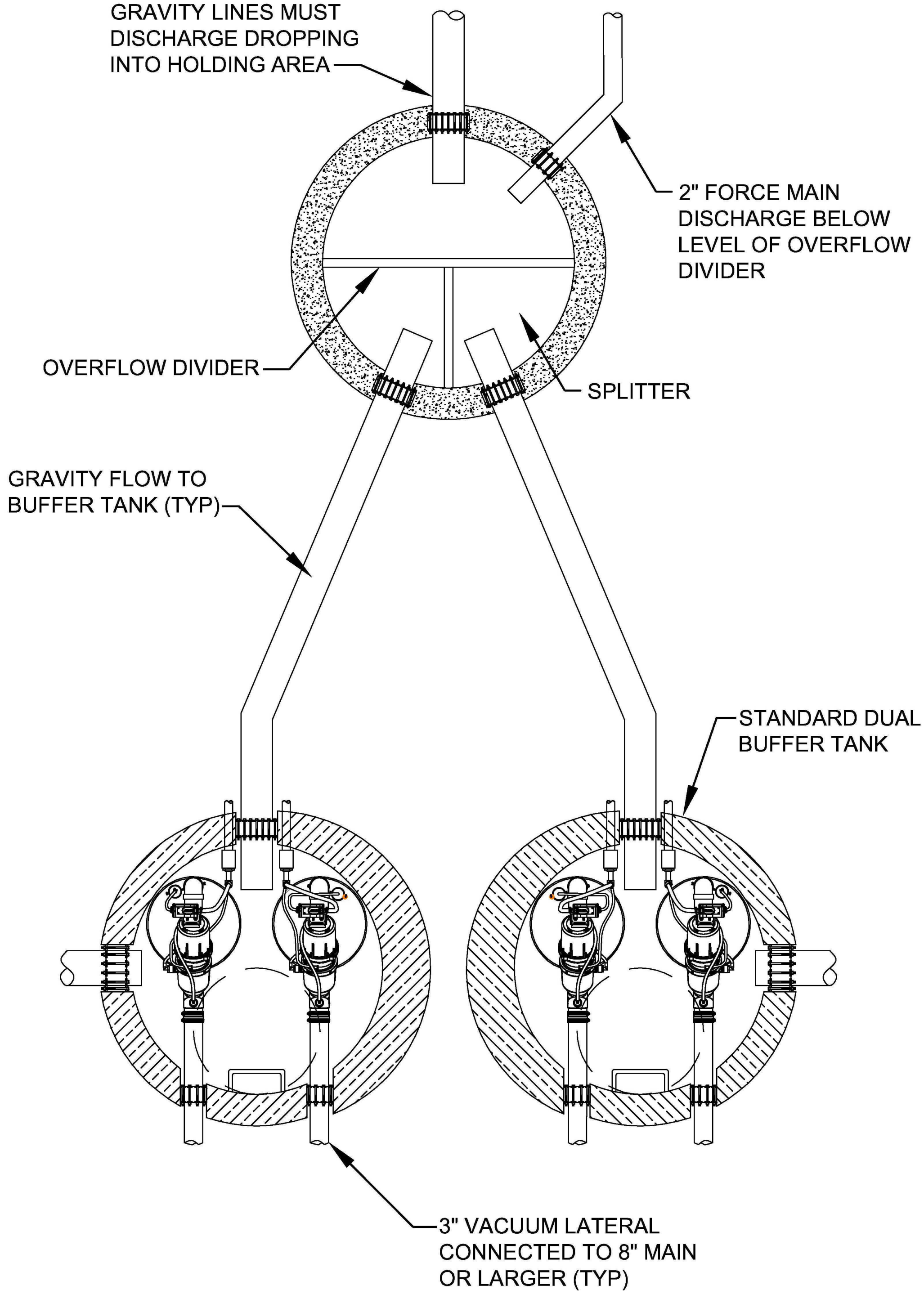


FIGURE 7-4: TWO DUAL BUFFER TANKS WITH SPLITTER MANHOLE

I. DO'S AND DON'TS

Table 7-5

Do's and Don'ts: Buffer Tanks

DON'T DO THIS:	DO THIS:
Use an in-sump breather for a buffer tank	Use an external breather and a 6-inch dedicated Air-Terminal for all buffer tanks
Allow more than 25% of peak flow to enter the system via buffer tanks w /out Airvac's approval	Limit peak flow entering system via buffer tanks to 25%, Consult Airvac to request higher limit on a case by case basis.
Allow more than 50% of peak flow to enter any single flow path via buffer tanks w /out Airvac's approval	Limit peak flow entering any flow path via buffer tanks to 50%. Consult Airvac to request higher limit on a case by case basis
Use buffer tanks when individual valve pits could otherwise be used	Use buffer tanks for larger flows only when service is possible at just one or two locations
Use buffer tanks at line extremities	Contact Airvac if service at line extremities is necessary
Exceed recommended capacity of single and dual buffer tanks w/out Airvac's approval	Use SBT for peak flows up to 15 gpm and DBT for peak flows up to 30 gpm Consult Airvac to request higher capacities on a case by case basis
Size a buffer tank using conventional peak flow figures when the buffer tank is connected to a lift station or grinder pump	Use the rated discharge capacity of the pump to size the buffer tank.
Connect a buffer tank to an undersized vacuum main	Use a minimum 6-inch main for a SBT and a minimum 8-inch main for a DBT

CHAPTER 8
SYSTEM ALARM AND MONITORING

A. OPTIONS

Airvac offers several alarm and monitoring options for valve pits, vacuum mains, and the vacuum station.

Table 8-1

Alarm & Monitoring Options

OPTION	VALVE PIT	VACUUM MAIN	VACUUM STATION
Telephone Dialer and/or SCADA (standard on all systems)	Not directly monitored but low vacuum detected at the station could indicated a valve pit issue	Not directly monitored but low vacuum detected at the station could indicated a valve main issue	**Alarm & Monitor** Tank levels, vacuum pump & sewage pump real time operating conditions
Wireless Light alarm	**Alarm** Valve open/closed	n/a	n/a
Wired alarm & monitoring	**Alarm & Monitor** Valve open/closed; high level in sump; valve cycle count & vacuum level at pit	**Alarm & Monitor** Vacuum pressure at the end of the vacuum main(s)	Could include SCADA
Wireless alarm & monitoring	**Alarm & Monitor** Valve open/closed; high level in sump; valve cycle count & vacuum level at pit	**Alarm & Monitor** Vacuum pressure at the end of the vacuum main(s)	Could include SCADA
SMART System	n/a	**Monitor & auto adjust** Vacuum pressure in mains; remote adjustment of air/liquid ratio	**Alarm & Monitor** Tank level; vacuum pump & sewage pump real time operating conditions
SMART Plus	**Alarm & Monitor** Valve open/closed; high level in sump; valve cycle count & vacuum level at pit	**Monitor & auto adjust** Vacuum pressure in mains; remote adjustment of air/liquid ratio	**Alarm & Monitor** Tank level; vacuum pump & sewage pump real time operating conditions

B. TELEPHONE DIALER AND/OR SCADA

Standard equipment at all Airvac vacuum stations include either a telephone dialer or more sophisticated SCADA equipment.

Telephone dialer

A voice communication-type automatic telephone dialing alarm system is typically used to alert the operator of system abnormalities and station emergencies. These are self-contained and capable of automatically monitoring up to four independent alarm conditions. Dialers using either a land line or a cellular connection are acceptable.

The telephone dialer is usually mounted through the face of the Motor Control Panel enclosure. If available, it is recommended that cellular service be used rather than hard-wired phone lines. If phones lines are used, provisions must be made to isolate the system from interference. The monitoring system should be provided with continuously charged batteries for 24 hours standby operation in the event of a power outage.

SCADA

Supervisory Control and Data Acquisition (SCADA) is a control system architecture that uses programmable logic controllers to interface with the vacuum station equipment and report data to a central location. Most commonly monitored conditions are the collection tank levels, vacuum pump operating conditions and sewage pump operating conditions.

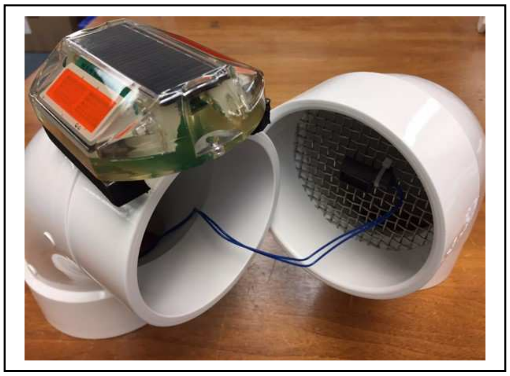
C. WIRELESS LIGHT ALARM

Airvac offers a wireless light alarm system featuring a solar powered light and a reed switch that is activated by air flow. This is the simplest and least expensive way to find a valve failing in the open position (hung valve) as it allows the system operator to visually see a valve that remains in the open position.

Solar Light in a road stud enclosure-mounted on 4-in. Air Intake

This device provides a visual indication of the vacuum valve's position (open or closed). A solar-powered light, with a 15-second delay feature, comes on when the valve opens and goes off when the valve is closed. The light includes 4 bright LED's visible from 800 feet contained in a road stud enclosure which is fully encapsulated. Rechargeable batteries with a 3-year continuous-use life and solar panels power the light which is mounted on the 4-in. air-intake.

An air switch mounted in the air intake is activated by air flow in the gravity piping and is connected to the solar light by wires within the air intake. No wires are required back to the valve pit or vacuum valve.



Solar Light in road stud enclosure installed on air-intake

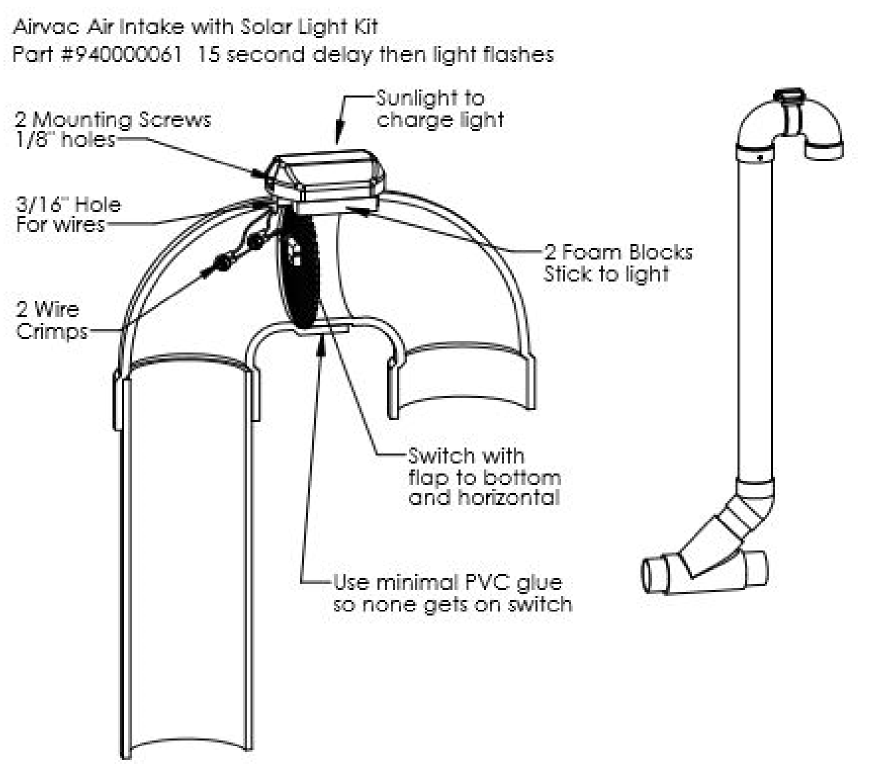


FIGURE 8-1: SOLAR LIGHT ALARM ON AIR-INTAKE

Solar Light in a road stud enclosure-mounted on 6-in. Air Terminal

The same solar powered light as previously described is used but is mounted on the Airvac 6-in. Air Terminal with the air switch mounted at the base of the Air Terminal.

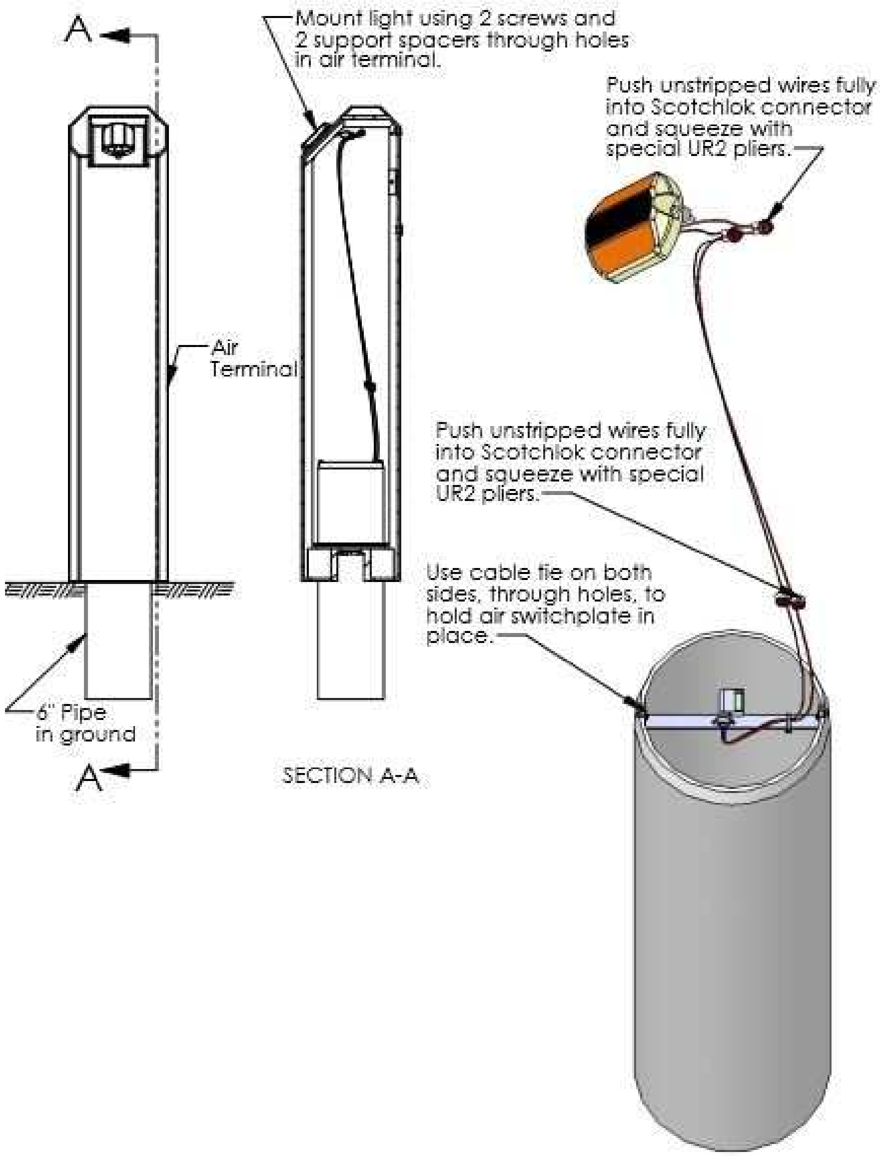


FIGURE 8-2: SOLAR LIGHT ALARM ON AIR TERMINAL

NOTE: Airvac also offers a wired light alarm system which uses hard wiring between the solar light and the AVPS magnetic sensor on the Airvac vacuum valve in the valve pit. Because it is directly hard wired, this system may be a little more dependable than the wireless method; however, it is more expensive as is requires more material and additional labor to make the connection.

D. WIRED ALARM & MONITORING

The Airvac Wired Valve Pit Monitoring system uses a network of low voltage wire buried parallel to the vacuum main trench during construction. Each valve pit is equipped with a waterproof box containing a Dupline sensor module capable of sending digital signals via the buried wire to a PLC at the vacuum station. Within the valve pit, a factory supplied quick wiring harness is easily connected from the existing Airvac valve to the module. Valves failing in the open position are detected as are valves that fail in the closed position (by detecting a high level in the sump).

For this option, Airvac provides the Dupline modules for the valve pits (housed in the Airvac Air Terminal or other nearby structure such as a post) as well as a server at the vacuum station. The contractor is responsible to provide and install the low voltage wire. The Engineer's design must include details (specs) on the wire and Dupline equipment as well as installation instructions for the contractor.

This functions as both an alarm system which pinpoints a valve failure, as well as a monitoring system that monitors all valves on a real-time basis. This will result in less time to find a problem, a more efficient system and ultimately lower O&M costs.

E. WIRELESS ALARM & MONITORING

The Airvac Wireless Valve Pit Monitoring System transmits valve pit data and end of line vacuum levels to a central SCADA system which is located at the vacuum station. The wireless data from each vacuum valve pit is transmitted via a mesh system in which communication occurs from a wireless unit to other nearby wireless units with the signal ultimately transmitted to the vacuum station SCADA system. With this system, the operating personnel can see exactly how each valve pit is functioning in real time.

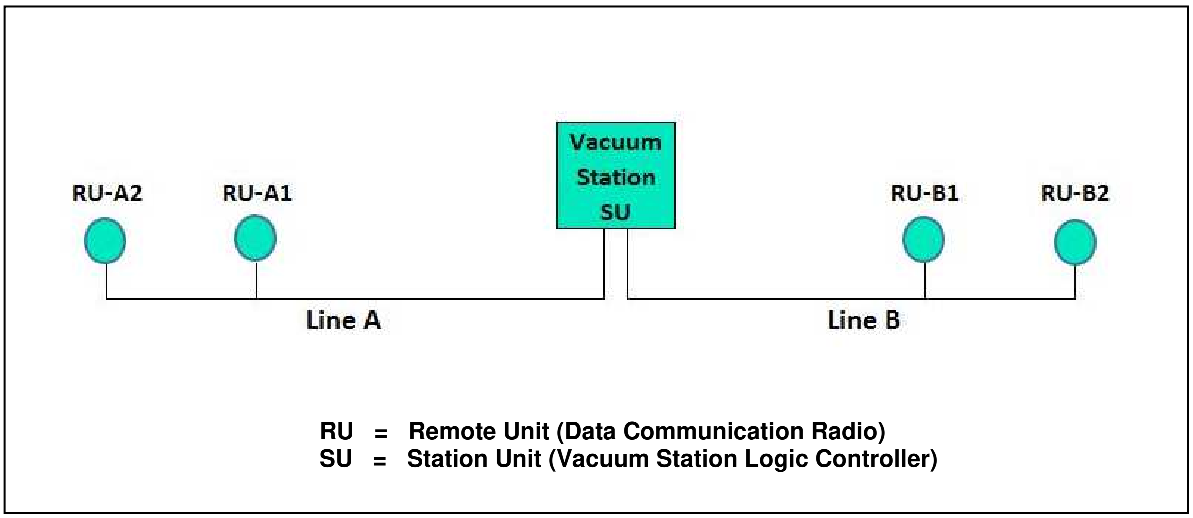
A factory supplied quick wiring harness easily connects the Airvac valve to a battery powered radio transmitter. The radio transmitter is typically housed in the Airvac Air Terminal located adjacent to the valve pit. As an option, the transmitter can be housed within the pit itself by using a traffic rated composite valve pit lid. Battery conserving methods allow for the quick transmittal of signals without sacrificing battery life. The selected battery is designed to withstand the temperature fluctuations that are expected and has a useful life of approximately 3 years.

All pertinent data from each valve pit is collected and saved to allow for analysis and adjustment if necessary. This "trend" feature tracks the operation of each valve pit and notifies the operator of imbalances within the system which allows the operator to proactively address potential problems before they occur. An additional feature is the ability to pin point a problem when it occurs. An alert will be sent to the operator and the exact location of the failure will be identified. This results in quicker operator's response time, fewer homeowner disruptions and lower O&M costs.

F. SMART SYSTEM (Strategic Monitoring for Advanced Remote Transfer)

Airvac's wireless SMART system controls the behavior of the vacuum collection system by not only monitoring each vacuum main, but also by making automatic adjustments in real time to optimize system hydraulics.

Key components include one (1) SMART PLC with a touch screen operator interface located in the vacuum station and multiple Remote-Control Boxes connected to dedicated valve pits located at strategic points within the collection system. The Remote-Control Boxes use solar powered radios to communicate with the SMART PLC. The SMART PLC then communicates with the various vacuum station controls and will override pump control as necessary to provide optimum system operation.



SMART System software uses several modes to identify system imbalances and provide recovery options. This may include monitoring various system vacuum levels, monitoring pump operating parameters, monitoring incoming flows, actuating remote vacuum valves, and adjusting vacuum levels at the station

A "purge" cycle can be programmed into the PLC that will automatically clear the vacuum mains at predetermined times to ensure that waterlogging of the system during critical times will not occur.

G. SMART PLUS

Airvac's SMART Plus system combines the wireless valve pit monitoring system with the wireless SMART system to provide complete vacuum collection system monitoring and automatic adjustment of its behavior.

CHAPTER 9
AIRVAC SERVICES

A. AIRVAC SERVICES

Airvac believes in the team approach where we assist the engineer, contractor, and owner in all phases of the project.

Table 9-1

Airvac Services
Planning, Design & Construction Phases

PROJECT PHASE	AIRVAC SERVICE
Planning	Preliminary system layout & budget estimate
Design	Detailed design assistance
Construction	Field Services/daily testing
Start-up	System start up – lines & station

Decisions regarding construction field services and start-up services must be made by the engineer during the design phase. Contract documents need to address these services. Separate bid items for these services are suggested.

Table 9-2

Airvac Services
Post-Construction Phase

PROJECT PHASE	AIRVAC SERVICE
Initial operation	Initial system operation
Home hook-up	Plumbers class/valve installation
Operator training	Operator training at factory/on-site
Continual Operation	Contract maintenance
After-market	Technical support/operation services

B. PRELIMINARY SYSTEM LAYOUT/BUDGET ESTIMATE

Upon receipt of some basic project information, Airvac engineers will assist consulting engineers with the preparation of a preliminary system layout as well as a budget estimate. This information will be included in a web-based proposal package that allows the recipient to view everything included or only that which is of interest.

System layout/preliminary design/Technical information
A preliminary system layout including vacuum main sizing will be provided. Preliminary sizing of the vacuum pumps, sewage pumps and the collection tank will be presented. The estimated quantities of the various system components will be identified. Technical information will be provided that summarizes the design assumptions, line and station sizing, and the valve pit quantities required. Embedded videos, case studies of other vacuum projects and links to various topics are also included in the proposal package.

Cost information
A budget estimate will be provided that includes an estimate of both capital costs as well as the annual Operation & Maintenance costs.

C. DETAILED DESIGN ASSISTANCE

When a consulting engineer commences the detailed system design, an Airvac engineer will be available for design assistance ranging from engineering training to hands on design work. An Airvac engineer will also review the completed design to verify the aspects of the design that relate to the Airvac system.

Line profiling assistance
Airvac can provide assistance with vacuum main profiling. Typically, this includes assistance with profiling the most critical vacuum main. Airvac will review the line profiles when completed and do a hydraulic analysis of both static loss and friction loss.

Plan and Profile sheets
Each design firm has their own style and ideas on how much detail to include on the plan and profile drawings. Information that typically is included in other utility design work should be included in vacuum sewer plans as well. In addition, there are certain vacuum-specific items that need to be shown as well. Table 9-3 shows some of the critical vacuum-specific items that Airvac encourages designers to include when preparing the P&P sheets.

Table 9-3
Key features to include on the Plan & Profile sheets

ITEM	WHY IS THIS NEEDED?
GENERAL	
Horizontal & vertical scale (Ex: 1" = 50'; 1" = 5')	Design review, bidding & construction purposes
Bar scale	Plans are sometimes reduced for printing
PLAN VIEW	
Flow arrow	To clearly indicate direction of flow
Length, size & type of pipe (Ex: 320 lf- 8" SDR 21 PVC)	For review, bidding & construction purposes
Pipe termination	For bidding & construction purposes
Branch line connection	To clearly indicate the use of wye fittings
Division valves	For bidding & construction purposes
Houses/lots to be served	To indicate which houses/lots share a pit
Slab or basement elevation (Ex: El 110.25)	For pit depth determination
Valve pit location and callouts	
Valve pit designation (Ex: VP – A23)	For construction purposes & maintenance records
Valve pit type & depth (Ex: 3030P1)	To establish product quantities
Valve pit rim elevation (Ex: El 103.50)	Combined with slab elevation & pit type this will be used to determine if the pit is deep enough to serve the intended house(s)
Valve pit stub-outs	To determine pit orientation & stub-out lengths
PROFILE VIEW	
Flow arrow	To clearly indicate direction of flow
Valve pit locations	To insure they are not too close to the top of a lift
Pipe length, size, type & slope (Ex: 320 lf-8" SDR 21 PVC @0.20%)	For review, bidding & construction purposes
Pipe termination	For bidding & construction purposes
Division valves	For bidding & construction purposes
Inverts - top & bottom of lifts	To indicate lift heights
Inverts - change in pipe slope	For construction purposes
Inverts – branch to main connection	To insure sufficient 'over the top' spacing

There are many ways to graphically present the items shown in Table 9-2. For example, some firms like to repeat plan view information on the profile view to act as a cross-check. Others prefer not to do this as changes made in one view during the design may inadvertently be missed in the other view resulting in conflicting information. Each method has its pros and cons.

Airvac has no preference on ***how*** the information is presented, but rather is more concerned on ***what*** information is included on the plan & profile sheets. As a general guideline, the designer should consider the following when deciding on the format used for the plan & profile sheets:

- Bid-ability and constructability. Is there sufficient detail for bidders to fairly price the job and for contractors to properly construct the system?

- Airvac review. Is there sufficient information to allow Airvac engineers to review for the design for compliance with the guidelines contained in this manual, and to allow for a hydraulic review to be completed (static & friction loss)?

- Regulatory agency review. Is there sufficient information to allow a regulatory agency to review for compliance with rules and regulations?

- Owner and operator use. Is there sufficient information to serve as basis for the as-built drawings and for future maintenance records?

Station skid drawings
Detailed drawings of the various skid arrangements are available from Airvac.

- Plan & section: skid assembly
- Control panel layout
- Power distribution
- Vacuum/sewage pump controls
- Electrical wiring
- Alarm/level controls
- Point to point wiring

Contact Airvac's Engineering Department for assistance with skid drawings.

Standard details
Airvac maintains an excellent inventory of standard detail drawings. These details are periodically updated to include new products, product changes, etc. Contact Airvac's Engineering Department for a copy of the latest standard details.

Sample Specifications
Airvac can provide detailed specifications using the Construction Specifications Institute (CSI) format for the vacuum-related aspects of a project, including:

- Valve & valve pit equipment Specifications
- Pre-Fabricated Vacuum Station Specification with Electrical
- Custom Constructed Vacuum Station Specification with Electrical

Contact Airvac's Engineering Department for format and availability.

Use of Airvac-supplied drawings & documents
Any Airvac drawing or other documents provided by Airvac during the design phase are done so with the understanding that they can be used in the final construction documents only if Airvac is chosen as the vacuum system supplier.

DISCLAIMER: *Airvac is not an engineering firm, and cannot and does not provide engineering services. Airvac reviews the design, plans, and specifications for a project only for their compatibility with Airvac's vacuum products, and accepts no responsibility for the overall project design. Any information provided to project engineers is provided solely to assist the engineer in designing and engineering and maintaining an overall system that can utilize Airvac vacuum products.*

D. CONSTRUCTION FIELD SERVICES

In our nearly 50-year history, one simple fact stands out: ***No matter how good the design, a vacuum system that is not constructed properly will experience problems.***

A correct installation is vital to the ultimate success of a vacuum system. Airvac can provide skilled field representatives to advise and assist contractors and consulting engineers with the construction of Airvac systems.

In most first-time vacuum projects, Airvac recommends that a Field Representative be present during the entire construction period. For repeat clients, or for projects where a consulting firm with vacuum experience is involved, Airvac can also provide part time field services.

Preconstruction (applies to both Full-time & Part-time services)
Airvac will provide a field representative to conduct initial training and assist the Owner and/or contractor with vacuum line and valve pit installation on site.

In this effort, service includes training of the consultant's Resident Project Representative (RPR), the Owner's utility operations staff and its designated contractor personnel on understanding the critical areas of laying vacuum main (grade, distances, elevations, and vertical profile changes), proper materials usage, proper trench conditions and bedding techniques, and appropriate testing procedures. Training services will also include review procedures to ensure that assembly, installation, and testing of Airvac's valve pit packages are being accomplished in accordance with Airvac standards.

Duties During Construction (Full time service only)
Daily site inspections insure that proper installation techniques are being followed by the contractor and proper monitoring techniques are being followed by the contractor and consultant's RPR.

Duties will include the following when applicable:

- Provide system operator with on-site training for station operation, valve installation and system operation.

- Spot check type of pipe, fittings and divisions valves being used to insure they are suitable for vacuum service. Review findings with contractor and Owner's design consultant accordingly.

- Review installation requirements with contractor and Owner's design consultant and verify that vacuum lines are installed as indicated on the contract drawings plans by spot-checking grades, distances and elevations.

- Observe and review general trench conditions with contractor and the Owner's design consultant to insure adequate soil conditions exist, and that proper bedding and compaction are carried out in accordance with the contract documents.

- Observe and review branch and service lateral installations with contractor and the Owner's design consultant to insure compliance with the contract documents.

- Provide on-site training on use of the Trailer Mounted Vacuum Pump (TMVP).

- Observe and review vacuum testing of vacuum sewers with contractor and the Owner’s design consultant to insure compliance with the contract documents.

- Provide coordination and supervision to the Owner, contractor and the Owner’s design consultant personnel during the final 4-hour vacuum main test and line flushing.

- Observe, review, and inspect valve pit sump testing with contractor and the Owner’s design consultant to ensure that testing is conducted in accordance with the contract documents.

- Review equipment storage and handling procedures with the contractor and the Owner’s design consultant to mitigate loss and/or damage to Airvac products used at the project site.

- Review field penetrations with contractor and the Owner’s design consultant to verify that Airvac products are neatly cut, reasonably circular and are located properly.

- Review valve pit assembly with contractor and the Owner’s design consultant to verify placement in accordance with contract documents.

- Review service lateral installation with contractor and the Owner’s design consultant to verify proper alignment with suction pipe.

- Verify that contractor and the Owner’s design consultant are implementing proper installation depths in accordance with contract documents.

- Review pit assembly installations with the Owner’s design consultant and contractor.

- Verify that a complete and accurate set of valve pit installation forms is being maintained by the Owner’s design consultant and contractor.

- Observe and train contractor and the Owner’ design consultant in the testing and installation of the homeowner’s gravity sewers to insure no infiltration exists.

- Check and review alignment of wall penetrations for vacuum mains and force main at the vacuum station with contractor and the Owner’s design consultant.

Duties During Construction (Part-time services only)
Airvac will provide periodic site inspections as determined by the Owner. The Owner will coordinate attendance by the consultant's RPR. These inspections are to ensure that proper installation techniques are being followed by the contractor and proper monitoring techniques are being followed by the contractor and consultant's RPR.

During these site visits, Airvac will review field installations for general compliance with Airvac and contract requirements, review "record" drawing markups (provided by the contractor) regarding grades, distances, elevations, and profile changes, and review test results on vacuum main and valve pit packages. Results of the reviews will be discussed with the Owner, the contractor, and the Owner's design consultant as necessary.

The Field Representative's duties during the construction period generally are the same as described under the Full-Time option, although some duties may be compromised by the Field Representative not being on the job site on a continual basis.

Construction Closeout (applies to both Full-time & Part-time services)
The Owner or its contractor shall coordinate one final closeout site visit and inspection from Airvac when the project has achieved final completion, but prior to startup. Services to be provided by Airvac to the contractor during the close-out stages of the construction will include:

- Review of final installations for compliance with Airvac and contract requirements.

- Site inspection to insure all Airvac components have been installed to contract specification.

- Review and acceptance of record drawings with regard to grades, distances, elevations, and profile changes

- Final review and acceptance of contractor test results on vacuum main and valve pit packages

After Airvac's field representative is satisfied that the Project has been completed to specification, the Owner, or its design consultant RPR will direct the contractor to perform a final 4-hour tightness test on the collection system in accordance with the provisions contained in the Owner's contract documents.

This construction closeout service visit is separate and in addition to Airvac's final start-up services, which is detailed in Part E.

E. SYSTEM START-UP

At the job-site, an Airvac Technician(s) conducts all the tasks related to the vacuum station start-up. The Contractor, with Airvac's help, does the collection system start-up tasks.

Note: similar tests to those described below for the vacuum station will be done by Airvac at the factory prior to shipment of the vacuum station equipment. A factory start-up report will be available upon request.

Vacuum Station Start-up
Airvac will provide the Owner's contractor with one or more technician(s) as necessary to complete the vacuum station start-up services. These technicians will be available to the contractor on-site to satisfactorily test the vacuum station equipment such that the equipment is ready to be placed into operation.

The contractor is responsible for coordinating startup activities between all parties; the Owner's design consultant, the contractor, Airvac and the Owner prior to the vacuum station start up. The following shall be completed prior to the initiation of start-up: a complete and operable force main, permanent power to the building, and a water source for filling the force main. The contractor should coordinate with all parties regarding level of effort and activities required prior to commencing testing.

The Airvac technician will coordinate and run all the tasks related to Airvac's vacuum station skid start-up. The contractor will assist in this effort as agreed to between Airvac and contractor. General **vacuum station** start-up duties include, but are not limited to, the following:

- Adjust the operating vacuum range, setting the low vacuum alarm level, and testing (verifying) the vacuum pump capacity rating.
- Once the electrical power supply has been checked and verified by the contractor, the vacuum system will be operated through various scenarios to verify that all delays, sequencing, and alarms are working properly. All controls will be adjusted to the appropriate levels for optimum system performance.
- Verify sewage pump motor rotation, check pump capacity and check discharge pressures.
- After a successful vacuum tightness test, water will be introduced into the collection tank by the contractor, so that the sewage pumps can be primed for operation. Once primed, additional liquid will be added to the collection tank to verify level control activity and that system lockout occurs at the appropriate level.

- Once verification that the controls are working properly occurs, the system will be placed in the automatic mode to verify that all delays, sequencing, and alarms are working properly. All controls will be adjusted to the appropriate levels for optimum system performance.

- Perform a complete electrical installation review is done to ensure proper operation of all equipment. The technician will verify that incoming voltages are at their required levels and then verify that voltages and amperages are correct for all vacuum motors in the station.

- Verify that system level probes are set to match the desired levels of lead and lag pump start, lead and lag pump shut-off, high liquid level alarm, high level lock-out, and system reset.

- Verify that the vacuum station is isolated from the collection system and a final vacuum test is conducted of all station piping.

- Once the electrical system has been checked out, a 4-hour tightness test will be placed on the system to insure the integrity of the collection tank and pipe work in the station.

- After the above has been completed, the technician will observe various other components (i.e.-sump valve, vacuum pump isolation valve, etc.) and any items unique to the system for proper installation and operation.

- After the collection system start-up is completed, the technician will return the station to its appropriate operational levels and then place the entire system in the automatic mode for commissioning into active service.

- A start up report will be written and furnished to the appropriate parties following the successful completion of the system start up.

Following the on-site start-up, the Airvac technician will switch the control panel power to the “on” position, turn all pumps to the “off” positions, and close the incoming and outgoing lines at the collection tank.

When R5 vacuum pumps are used, the butterfly valves to the vacuum pumps will be closed and the vacuum pump immersion heaters will be adjusted to 150ºF. The immersion heaters are installed to prevent moisture from accumulating in the vacuum pumps, but they will not remove moisture from the oil. These measures are taken by Airvac to protect the equipment and pumps from water and/or moisture damage. This procedure is not necessary when Mink pumps are used.

Vacuum collection system Start-up

For the **collection system** start-up, Airvac will coordinate tasks with the contractor's assistance. The contractor will perform such activities not specifically requiring Airvac's expertise, as may be agreed between the parties. The contractor is responsible for coordinating startup activities between all parties; the design consultant, the contractor, Airvac, and the Owner prior to the collection system start up. Prior to the initiation of start-up, the contractor must have water available to fill the ends of each vacuum line.

General **collection system** start-up duties include, but are not limited to, the following:

- Once the vacuum station has been checked out successfully, including the successful tightness test on the station equipment, the Airvac technician will begin start-up of the collection system. The isolation valves between the collection tank in the station and the collection system line work will be opened and the entire vacuum station and collection system will be placed under vacuum.

- The contractor will place the entire system under a 4-hour vacuum tightness test in accordance with the contract documents to insure the integrity of the vacuum station and collection system piping.

- After the Airvac technician verifies that the final 4-hr vacuum test results meet the provisions set forth in the contract specifications, Airvac and contractor will coordinate to introduce water into the collection system at the far extremities of the lines and other various points throughout the collection system to systematically flush any debris that may have entered the system during construction to the station. The contractor will then remove the man-way cover on the collection tank and evacuate the liquid by means other than the station discharge pumps, also removing any debris that may have accumulated.

- Following the successful completion of line flushing, the Airvac technician will return the station to its appropriate operational levels and place the entire system in the automatic mode for commissioning into active service.

- A start up report will be written and furnished to the appropriate parties following the successful completion of the system start up. The Airvac technician will attend a follow-up meeting with the design engineer and the Owner to review the results of the collection system and vacuum station start-up procedures.

NOTE: In projects where the vacuum station and the collection system are in separate contracts, coordination between all parties is even more important. Coordination will be the responsibility of the Engineer and/or Owner.

F. INITIAL SYSTEM OPERATION

When a system first goes on line, the system Air to Liquid ratio, and the overall system hydraulics, will change with every valve that is installed. To help the Owner during this critical time, Airvac can assist during the early stages of system operation.

G. HOME HOOKUP & VALVE INSTALLATION

Along with system start-up, this is one of the most critical stages of the entire project. Even a well-designed and constructed system can experience operational difficulties early on if the following activities are not carried out.

Public Education
To ease homeowner fears, Airvac can participate in various public education endeavors, including participation in public meetings, conducting tours of existing systems and participation in Owner sponsored workshops.

Plumbers Class
Airvac has found it to be very advantageous to conduct training classes with local plumbers who will be doing the home hook-ups. In some cases, the Owner will require the local plumbers to attend the Airvac class to become certified to install the homeowner's gravity line and connect it to the vacuum valve pit.

Home hook-up inspection & valve installation
Airvac can provide the Owner with inspection assistance regarding the homeowner gravity line connections to the valve pits as well as actual installation of the Airvac 3-inch valve. Specifically, Airvac will:

- Provide inspection of the homeowner gravity line in conjunction with plumbing inspectors. Airvac will help to ensure that all air intakes are in the proper locations, that sufficient slope exists on all piping and that the homeowner makes a proper connection to the Owner supplied gravity stub leading to the valve pit.

- Install the 3-inch Airvac interface valve in each valve pit after the homeowner plumbing inspections are completed and approved by the local plumbing inspectors and the Owner.

H. OPERATOR TRAINING

Training of the system operators is an important part of any sewage scheme. Airvac provides excellent operator training to ensure optimal system operation.

Factory training - Operator's school (recommended)

Airvac offers an operator training school conducted at the Airvac factory in Rochester, IN. The Airvac Operator Training Course is held at the end of each month, except December. For those states that accept it, continuing education units (CEU's) are provided to those completing the course. In additional to learning about the Airvac valve and controller, the attendee will also learn about the vacuum pumps, electrical control panel, troubleshooting, system adjustments and fine-tuning the vacuum system. The clear pipe test rig is utilized to demonstrate sewage conveyance using vacuum and to visually identify flow characteristics during normal and abnormal conditions. The class is taught by four Airvac specialists.

Training is provided on the following topics:

- Day 1: Facility tour, Introduction, Airvac App, Operation of Airvac demonstration system (Test rig), and O&M training.
- Day 2: Airvac controller training (AC-U)
- Day 3: Airvac controller training (HP controller), valve pit components, R&D topics, Introduction to electrical/mechanical equipment.
- Day 4: Introduction to Busch vacuum pumps, discharge pumps and Moisture Separator

On-site training

Airvac can also perform on-site training. This hands-on training would include troubleshooting tips, assistance with setting valves and the controller timing, and adjusting the vacuum station and vacuum valves to mirror the changing system hydraulics. Arrangements for other such training sessions can be made with the Airvac Service Department.

I. **CONTRACT MAINTENANCE**

Since our inception nearly 50 years ago, our focus has been on improving our products and providing our customers with the knowledge and resources to operate and maintain their systems efficiently and effectively. One such resource is operation and maintenance of the vacuum system on a contract basis. This service includes normal day-to-day maintenance, preventive maintenance, callout services, repairs and reports.

This Contract Maintenance service has several benefits to the Owner, all of which ultimately leads to extending the life of the Owner's investment. Contact Airvac's Service Department to learn about these benefits.

Staffing

Airvac is aware that choosing this option may result in the displacement of some of the Owner's existing maintenance staff. Airvac is sensitive to this possibility and as a result has developed a staffing plan to minimize this possibility. The plan includes temporarily relocating an Airvac Service technician to the project area and then hiring the displaced employee(s) to be part of our staff. Any additional staff that is necessary would also come from the local community. Regardless of the knowledge level of the staff, Airvac would provide a thorough training program resulting in each member being certified on vacuum sewer technology.

Operation & Normal Maintenance

Airvac will operate the vacuum collection system as needed to ensure the system operates as designed and constructed on a continuous basis. The system will be operated in a manner which provides reliable sanitary sewer service to the customers connected to the vacuum sewer systems. Operations will include, but is not limited to, the inspection and operation of the vacuum pump stations, valve pit valves and vacuum main division valves as needed to maintain proper operation of the system as designed and a check the operational hours of the standby generators (if present) at each vacuum station on a weekly basis.

Preventive Maintenance
Preventive maintenance of the vacuum station and vacuum collection system will be performed as specified in the following documents:

- Airvac Operation, Installation and Maintenance Manual

- Airvac Vacuum Collection System Operation and Maintenance Manual associated with each specific area of the project

- Operation and maintenance manuals provided by the manufacturers of Airvac-supplied system components

On an annual basis, Airvac will inspect and exercise the division valves on the vacuum mains and advise the Owner of any maintenance that needs to be performed in order for the valves to operate correctly.

Callout Service
Airvac will respond to customer complaints, respond to system alarms and provide repair or replacement of Airvac-supplied system components on a 24 hour per day, 7 days per week, 365 days per year basis, when immediate response is necessary to maintain continuity of proper and reliable system operation. Airvac will arrive at the site of the system failure within 60 minutes of notification by alarm, by the Owner or by other means.

Repair
Airvac will provide parts and labor to rebuild Airvac valves and controllers that malfunction during the contract term. This is not to be confused with Airvac's recommended preventive maintenance schedule for rebuilding valve and controllers.

Reports
Airvac will provide a report monthly to the Owner summarizing system activity for that period. This report will include:

- Run hours for all pump drives
- All preventive and corrective maintenance work performed
- A summary of service call-outs for the period by work order
- Any other information required by the Owner

Airvac will also provide an annual report to the Owner summarizing activity for each project area for that fiscal year.

Included In System O&M Scope of Services
The following provisions are included in Airvac's scope of services:

1. Airvac will provide proper uniforms to their employees that will identify them as Airvac staff contracted to perform work on behalf of the Owner.

2. Airvac employees will display photo ID's in a prominent location on their person.

3. All vehicles used to service the Agreement will be identified as Airvac's.

4. Airvac will maintain good housekeeping habits inside the vacuum stations.

5. Airvac will maintain a reasonable stock of spare parts required for continuous and reliable operation of Airvac-supplied system components.

J. OTHER AFTER-MARKET SERVICES

Technical support from the Airvac Engineering and Service departments provide any necessary support to assist the owner in providing timely information and solutions to problems.

24/7 Technical support
Airvac provides on-site technical support to the owner during system operation and in emergency situations as required. With our toll free 800#, service assistance is available 24 hours a day, 7 days a week.

Problem Simulation
Airvac maintains a complete vacuum system at our factory that can be used to simulate field conditions and onsite problems to help solve owner problems or suggest solutions.

Annual System Evaluation & Tune-up
An Airvac technician will cycle and re-time all Airvac valves, conduct exterior leak tests on each controller and visually inspect each valve pit. The technician will visit each vacuum station to perform various equipment tests.

Response to natural disasters and emergencies
Airvac has been involved several times with the Federal Emergency Management Agency (FEMA) reacting to damage from floods, tornadoes, and hurricanes. We understand and work within the FEMA guidelines to restore service as quickly as possible.

Airvac will contact the system operator prior to offer standby assistance. Field personnel can be dispatched to help restore the system, if requested.

Spare parts
Airvac maintains an inventory of spare parts at our Rochester, IN facility. This includes every single part and piece that makes up our products. With this inventory, the owner can expect spare parts within 24 hours of their request.

K. STANDARD WARRANTY

Airvac has two standard warranties: one covering vacuum valves and other items manufactured by Airvac and one covering the Airvac vacuum station equipment.

Standard Two-year warranty *

Vacuum valves
Valve pits (all types)
Flotation collars
Flexible connectors
Trailer mounted vacuum pump (TMVP)

* *from the date of installation or 30 months from the date of shipment, whichever comes first*

Standard One-year warranty **

Vacuum station skid

** *from the date of installation or 18 months from date of shipment, whichever comes first*

L. WARRANTY PLUS

Airvac's WarrantyPlus program is available for a fee. This program is an extended warranty for the Airvac valve pit and vacuum valve* that also includes multiple weeks of Airvac field services at no additional cost. It is estimated that the cost of this extended warranty will be less than 1% of the overall project budget. Contact Airvac's Service Department for the latest fee amount

** This program does not apply to the vacuum station equipment.*

<u>*How it works*</u>

WarrantyPlus adds an additional 2 years warranty on the Airvac valve, controller and valve pit, making it a 4 yr warranty, while also providing free field services for 'x' number of weeks depending on the number of the valve pits on the project as shown below.

Table 9-4

WarrantyPlus Program

Level	**# of valve pits**	**# of weeks included**	**Max # of trips**
1	1 – 100	4	2
2	101-200	6	2
3	201-300	8	2
4	301-400	10	3
5	401-500	12	3
6	501-600	14	3
7	601-750	16	3

The client must purchase the extended warranty before the project begins. For the extended warranty to apply, an Airvac Service Technician must be onsite at certain times throughout the construction project.

Field services: Beginning construction- Owner, Engineer & Contractor

- Vacuum installation 101 training
- Vacuum valve pit and piping installation inspection
- Valve pit and pipe testing review

Field services: During construction- Owner, Engineer & Contractor

- As-built review
- Static loss review
- Valve pit and mainline testing review

Field services: After construction – Owner & Engineer

- Gravity lateral from house to valve pit observation
- Vacuum valve installation assistance
- Operation and maintenance training
- Initial operation and maintenance assistance

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