



Vacuum Sewers - Design and Installation Guidelines

An Online Continuing Education Course for Engineers

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Vacuum Sewers: Design and Installation Guidelines

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I. INTRODUCTION

From the time the very first public sewer system was constructed until the 1960's, a conventional gravity system was the only choice US engineers had when considering a public sewer collection system. This changed about 50 years ago when the USEPA challenged the industry to developed alternative collection by providing special funding for such endeavors. One of the alternative collection systems is vacuum sewers.

At one time, vacuum sewers were regarded as “new” and only to be used as a system of last resort. Improvements in the technology later led to acceptance as “alternative” sewers, but still only to be used when significant savings would result. Now, vacuum sewers have become an acceptable alternative in the proper application and are providing efficient and reliable sewer service to communities all around the world. However, proper design is of utmost importance for these systems to perform efficiently.

This course is Part II of a three-part series on vacuum sewers and will focus on detailed design and installation guidelines for vacuum sewer systems. Part I discusses the basics of vacuum sewer technology by providing a broad overview of the technology while Part III focuses on the Operation & Maintenance and System Management aspects related to vacuum sewers.

II. HOW IT WORKS

A. *Theory of Operation*

Vacuum sewerage is 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 (negative pressure) on the collection system. The system requires a normally closed vacuum/gravity interface valve at each entry point to seal the lines so that vacuum can be maintained. These valves, located in valve pits, open when a predetermined amount of sewage accumulates in collecting sumps. The resulting differential pressure between atmosphere and vacuum becomes the driving force that propels the sewage towards the vacuum station.

B. The process – from the house to the vacuum station

Figure 1 and the following discussion describe the vacuum sewer process of the wastewater's travel from the house to the vacuum station. A more detailed description of the major system components is found later in this course.

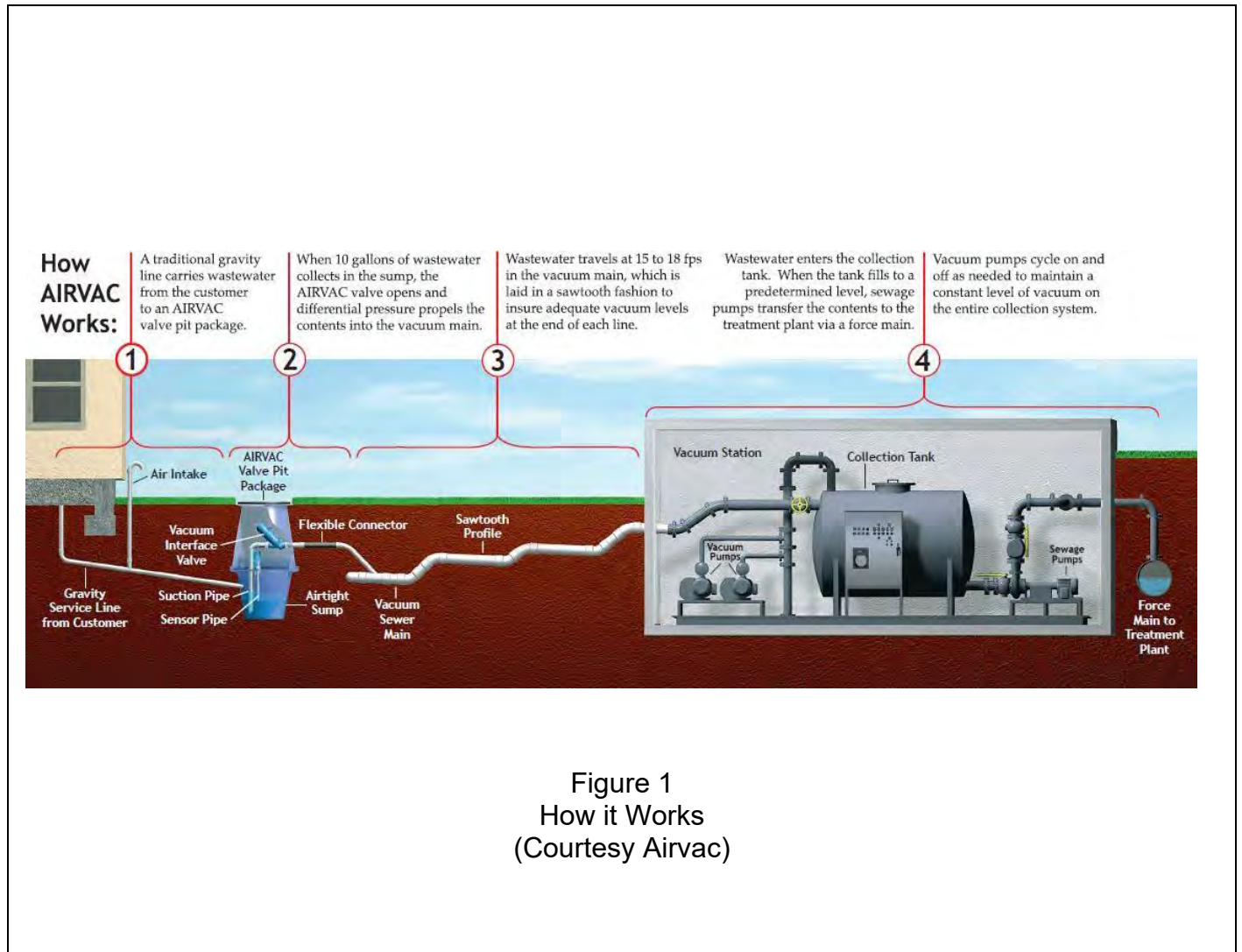
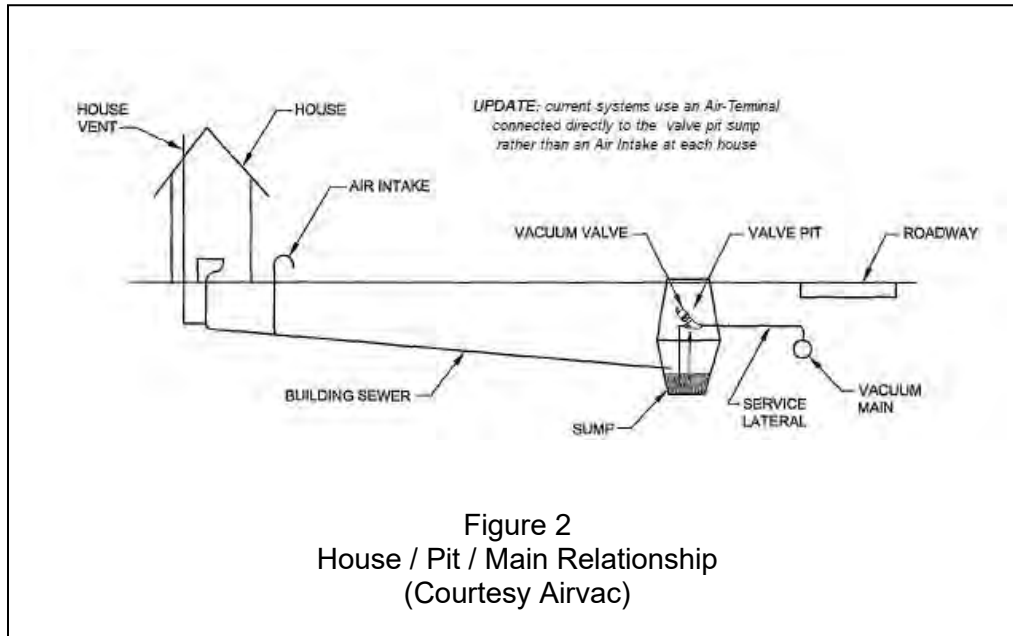


Figure 1
How it Works
(Courtesy Airvac)

House to valve pit

As far as the homeowner is concerned, connecting to a vacuum system is similar to connecting to any other sewer system. Sewage flows by gravity away from the house through a small diameter PVC pipe to the point of connection of the public sewer system (Figure 2). In this case, the point of connection is the valve pit.



In the valve pit

Vacuum created by vacuum pumps located at the vacuum station is transferred through the vacuum mains and to the valve pit. The valve pit is where the interface between gravity and vacuum occurs.

Housed in the top chamber of the valve pit is an interface valve. This valve is normally closed in order to seal the vacuum mains. This ensures that vacuum is maintained on the piping network at all times.

The lower chamber of the valve pit is a sump that receives the sewage from the house. When 10 gallons of sewage accumulates in the sump, the interface valve automatically opens. This is done without any electrical power being required. The valve opens and in 3-4 seconds, the contents of the sump are evacuated. The valve stays open for another 2 or 3 seconds to allow for atmospheric air to enter the system. This air comes from either the air-intake located by the house or an Air-Terminal device located adjacent to the valve pit and connected directly to the valve pit sump.

In the vacuum mains

The resulting pressure differential between the positive pressure of atmosphere air and the negative pressure in the vacuum main becomes the driving force that propels the sewage towards the vacuum station. The pressure differential that exists at the normal operating vacuum levels provides the energy to propel the sewage at velocities of 15-18 fps.

When the sewage enters the vacuum main it travels as far as its initial energy allows, until frictional forces cause it to come to rest. As other valves in the piping network open, additional slugs of sewage and air enter the system. Each subsequent energy input continues to move the sewage toward the vacuum station.

Many view the vacuum pipeline as a “vacuum-assisted gravity sewer”. Like gravity sewers, vacuum sewers are installed with a positive slope toward the vacuum station. When vacuum mains start to become deep, a “lift” is used to return the main to a more acceptable depth. It is at these lifts that vacuum “assists” the sewage on its travel toward the vacuum station.

The lifts are part of the saw-tooth configuration of the vacuum mains, which is a key feature of a vacuum system. The saw-tooth profile is used to keep an open passageway on the top of the piping network, thereby preventing the pipe from becoming sealed. By doing this, air flows above the liquid, and the vacuum that is created at the vacuum station can be transferred to every valve pit. This ensures that the maximum pressure differential, and hence, maximum energy, can be obtained at each valve pit.

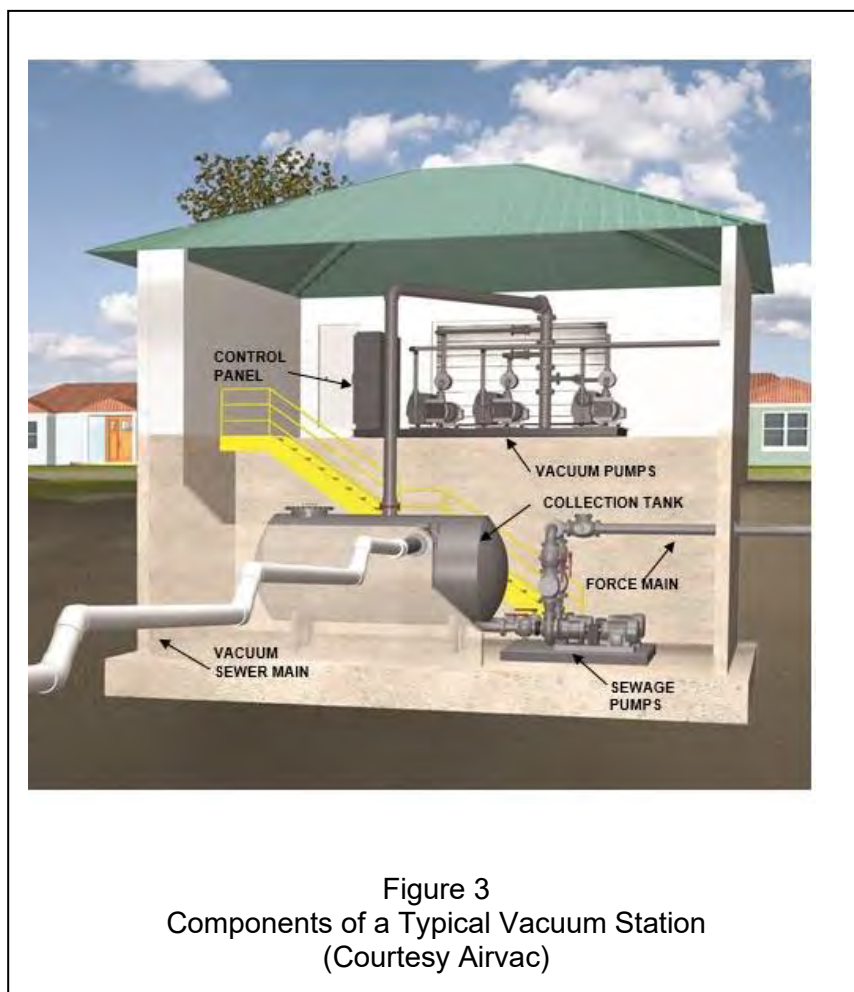
At the vacuum station

Eventually the sewage reaches the vacuum station. The vacuum station has 3 major components: the collection tank, the vacuum pumps and the sewage pumps (Figure 3).

The vacuum pumps and the vacuum mains are connected to the top part of the collection tank. This part of the tank is kept open so that the 16 - 20 in. mercury vacuum that is created by the vacuum pumps can be transferred to the vacuum mains and ultimately to the valve pits.

For many years, vacuum pumps were programmed to run in cycles. They were designed to run at full speed for a short period, usually 3 to 5 minutes, in order to establish the high level of 20-in. of mercury vacuum. When this level is achieved, they turn off. As valves throughout the system open and admit atmospheric air, vacuum levels gradually drop. When the vacuum level reaches 16-in. of mercury vacuum, the vacuum pumps come on again and run to re-establish the 20-in. of mercury vacuum. As the technology has progressed and advancements made in vacuum pumps, the vacuum pumps can now operate continually at variable speeds if controlled by Variable Frequency Drives (VFDs). By operating at variable speeds, the vacuum pumps match the vacuum demand of the system. The net result is a large reduction in power consumption and a more efficient system.

Sewage from the vacuum mains enters the collection tank and accumulates in the bottom part of the tank. When enough accumulates, the sewage pumps come on and pump the sewage out of the collection tank through a force main to the ultimate point of disposal.



III. SYSTEM DESIGN CONSIDERATIONS

This section provides a general overview pertaining to the design of the various components of a vacuum system. The reader is referred to the Airvac 2018 Design Manual¹ for additional and more detailed design information.

A. Hydraulics

All 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.

Design flows are maximum flow rates expected to occur once or twice per day and are used to size the vacuum sewer mains and the various vacuum station components. Instantaneous flow rates in excess of design flows can occur under certain situations.

Average Daily Flow (Qave)

Based on the current Ten State Standards, sewage flow rates shall be based on one of the following:

1. Documented records and
2. 100 gallon specific to U.S. Cens
- d. Water use
- population densities accept published

Peaking Factor (F)

The peaking factor exception: the mini used, with one 2.5.

If not established by regulations, the pea other applicable formula:

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

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