The Next Frontier

Vacuum Plumbing Systems

**Engineers and designers, take note:
VPS' water conservation and other benefits might be too much to ignore.**

By Mark D. Thayer, CPD

The California Gold Rush in the mid-1800s helped define a significant part of the culture on the American Frontier. At a time when currency was based on the gold standard, the newly mined gold provided an economic stimulus all across the North American continent. Despite the economic benefits, there were associated risks that caused many people to limit, or even avoid, participating. Nevertheless, many who accepted the risks and ventured down dusty trails benefited from their decision.

In the world of plumbing design, vacuum is the next frontier. Those with little knowledge of, or experience with, vacuum plumbing systems (VPS) may be like those who viewed the Gold Rush too risky. Most plumbing designers and engineers are comfortable with traditional DWV systems and see no reason to consider an alternative and certainly would not consider vacuum a pot of gold! However, as water shortages increase across the U.S., alternative approaches to traditional thinking must be considered.

As the U.S. population increases, higher demands for fresh water are becoming paramount environmental concerns. The EPA recently reported that water managers in 36 states anticipate water shortages in the next 10 years even under normal water conditions. In numerous areas where water wells are used for public-supply systems, subsidence due to over pumping is becoming critical. The chart shown in **Figure 1** (on page 23) identifies monthly-mean water levels from 1964 to 2003 for a USGS monitored water well in Cook County, GA. This chart clearly illustrates the long-term effects of over pumping of groundwater aquifers.

Part of a Permanent Solution

High-performance, water-conserving systems like vacuum plumbing systems may be a significant part of the permanent solution for water shortages. VPS utilize a specially designed toilet that uses nearly 70% less water than a conventional toilet. Conventional toilets (that comply with the 1992 EPACT standards) use 1.6 gpf, while vacuum toilets use 0.50 gpf.

For projects requiring LEED certification, several credits may be obtained by using a VPS due to the reduced flush rates. After calculating the project's base load case, the designer should evaluate the possibility of obtaining Water Efficiency Credits WE 2, 3.1 and 3.2. Vacuum will reduce the generation of wastewater and potable water demand. It also will maximize water efficiency within buildings to reduce the burden on municipal water supply and waste water systems. Also, Innovation & Design Process Credit ID 1 may be obtainable due to performance of the vacuum system above the minimum required by the LEED rating system.

Another benefit of VPS is its resistance to stoppages. While not completely clog-proof, the VPS consistently out-performs traditional systems in this regard. This is especially helpful in jails and prisons where inmates have been known to disrupt

Photo at right: VPS mains and other piping changing direction above ceiling (pipe caps serve as cleanout). **Background schematic:** Modular designed equipment room provides expandability and access for life cycle equipment replacement.

security operations by intentionally clogging water closets and even breeching the entire sanitary piping system by flushing clothing, bedding, or other items down the toilet.

Even if your project scope doesn't include LEED certification, green design, or security issues, other reasons exist to consider VPS. Some projects have specific architectural limitations, like floor slabs that cannot be penetrated for sanitary piping or buildings without chases, where conventional plumbing systems are difficult to install. VPS piping is typically installed overhead, so projects with limited chase space or other architectural limitations may be perfect candidates for a vacuum system.

VPS can be used in a variety of applications, including office buildings, hospitals/clinics, hotels, restaurants, retail stores and shopping centers, schools, sporting arenas, correctional facilities, and detention centers. Additionally, one wide use of VPS is in the removal of condensate water from refrigeration units, food display cases, and walk-in coolers in food courts and grocery stores.

In the world of the unknown, most equate unfamiliarity with higher design and construction costs. Some may be less than enthusiastic to pursue VPS technology due to first-cost considerations and to wondering how VPS compares to a conventional DWV system. There may be no absolute answer due to the uniqueness of each project. However, there are specific cost reduction benefits in VPS — such as reduced pipe size and the absence of significant underground piping — that yield significant cost reductions.

Once feasibility issues are resolved, certain design issues must also be addressed. For many years, plumbing load estimation and basic DWV design has been based on the prescriptive guidelines developed by Dr. Roy B. Hunter in the BMS 65 Report (National Bureau of Standards, December 16, 1940). However, at this point in time, there is no similar universally recognized approach for the design of VPS. This fact requires VPS design to be performed under the Code provisions of an engineered system.

The International Plumbing Code (IPC) allows and addresses such systems in Section 105.4, Alternative Engineered Design (2006 IPC). While manufacturers typically offer design guidelines, recommendations and support, the VPS design is solely the responsibility of the designer. So, as with any engineered type system, a

Figure 1. Monthly-mean water levels in Cook County, GA. Source: http://ga.water.usgs.gov.

Liquid ring vacuum pumps will be piped to collection tanks shown in background to evacuate waste from plumbing fixtures. Photo by Geoff Hankins.

level of design effort beyond conventional DWV systems is required. Therefore, one must apply specific scientific and technical knowledge for the design, analysis, and construction of vacuum systems.

Before including a VPS into a project, you must advise your client of several important issues from the onset. The first is that VPS are an evolving technology and, as a result, some with VPS experience may not have favorable opinions. Originally used in plumbing systems in aircraft, trains and boats, several of the first building-based projects were plagued with performance issues. Due to a continued commitment in the R&D of VPS from U.S.-based manufacturers, most of the initial problematic issues have been overcome.

The second issue to educate your client about is the benefits of investing in an engineered system. The client must be reminded that engineered systems which perform properly and are reliable are those that are properly designed, installed and maintained. Due to differing approaches to VPS technology, the owner may be best served with vacuum components provided from a sole source manufacturer. Therefore, the designer must establish appropriate procurement processes accordingly.

Finally, as with any mechanical system that operates properly, the owner must be willing to make a commitment over the life of the system to maintenance. The VPS will require different maintenance than a typical DWV system because it includes pumps, controls and components that may require periodic replacement and/or adjustment.

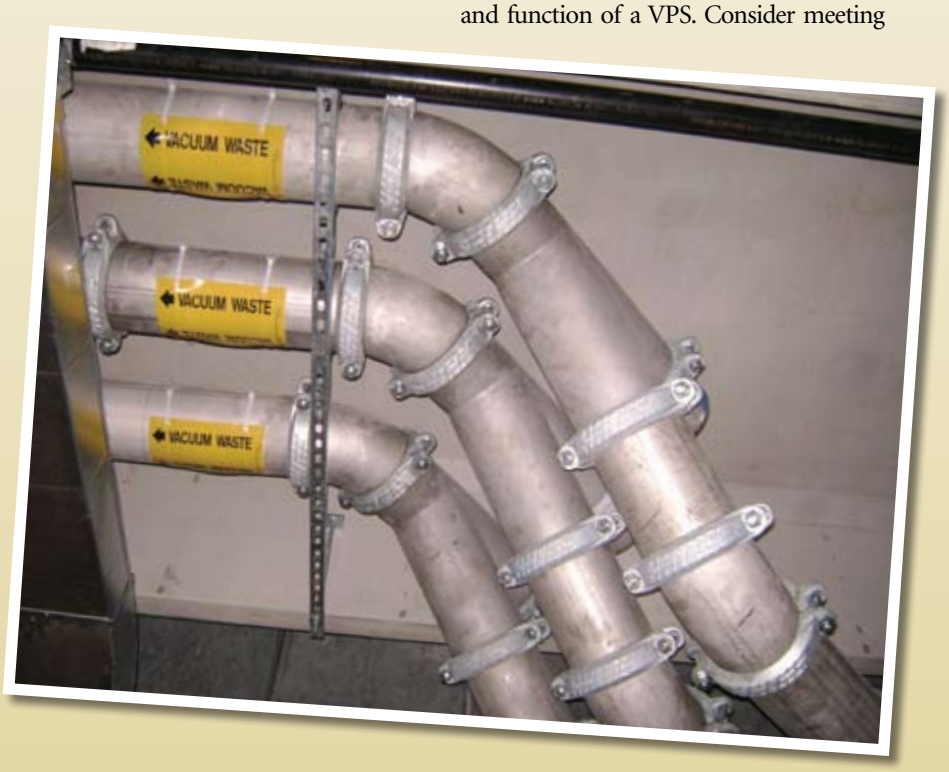
Administrative and Engineering Tasks

As the project design progresses, several administrative and engineering tasks are recommended. The designer should:

• Review applicable codes in effect for the given locality to determine requirements. Assuming that the system will be deemed an engineered alternative, approval from the code official to proceed with the design should be obtained.

• Evaluate the type of fixtures to be connected to the system and potential significant loading impacts. Connections and loads from water closets, floor and shower drains, fire protection test connections, sprinklers, grease waste connections, high temperature wastes, chemical waste, and other sources must be addressed. Certain waste streams may need to be excluded from connection to the system due to chemical incompatibility with pump seals and other components.

• Provide a submittal for the code official containing preliminary documents such as architectural floor plans, code analysis, and occupancy profile and site plan. Include manufacturer product literature addressing vacuum components, fixtures and function of a VPS. Consider meeting



Three 8-inch VPS mains above ceiling changing direction vertically and horizontally.

One-and-one-half-inch vertical lift piping from fixtures, with check valve and isolation valve connected to a horizontal branch main.

with the code official to present the submittal and answer questions. Indicate which fixtures will be connected to the system and discuss the method of calculations. Project experience has shown that the Code Official will likely be open to the engineered system if considered part of the team.

• During the schematic design, develop minimum service space requirements for the VPS components and coordinate with the project architect so service space requirements can be incorporated.

• Consider plumbing fixture chases where vacuum interface valves, isolation valves, controllers, accumulators and other components will be located. Typically, these items are located as close to the fixture as possible. Consider lighting in plumbing chases for ease of maintenance

Western Virginia Jail Features VPS

The Western Virginia Regional Jail is one the first major projects on the east coast to use a VPS and is likely to be the first LEED-certified jail facility in the U.S. With such bold initiatives, it was imperative to use systems that could assist in achieving the required LEED credits.

Project Overview

- Located in Roanoke County, VA, near historic Dixie Caverns
- Rated capacity of 1,254 inmates
- Serves Roanoke, Franklin, and Montgomery Counties and the City of Salem, VA
- Project cost = $94 million
- Project completion set for March 2009

Artist rendering of the Western Virginia Regional Jail located near historic Dixie Caverns in southwestern Virginia.

Plumbing Systems

- 100 hp VPS (expandable to 150 hp for future loads) with PLC/PC controls and a dedicated energy recovery system for hot water pre-heat
- Six copper fin gas-fired water heaters (10,800 MBH total capacity) with 1,500-gallon storage tanks
- Siphonic roof drain system
- 120,000-gallon rainwater harvesting system dedicated for laundry operation
- Schedule 10 stainless steel grooved piping systems for domestic water and vacuum plumbing systems

Pre-assembled, mechanically joined wye fittings awaiting installation above cell chases.

and access to piping components such as cleanouts and valves. Evaluate the space requirements for VPS equipment, including vacuum pumps, collection tanks, grinder pumps, discharge pumps, motor control center, piping and sufficient service space for each.

• As the piping plans are being developed, include pipe gradient, long radius-type drainage pattern fittings and cleanout provisions. Even though pipe slope is employed, space for overall slope depth is reduced by using a series of fittings called a slope make-up where system pressure forces the effluent back to a high point in the piping arrangement.

• Proper selection of VPS piping material for project suitability is critical. Typical piping materials are PVC, CPVC, stainless steel and DWV copper. Ends of the pipe must be capable of being reamed to be free of burrs, slag and/or depressions from roll-cutting processes, if used. Pipe joints must be capable of holding full vacuum pressure of 29" Hg. The entire system should pass a vacuum pressure test with a suggested minimum leak rate of .10" Hg/min.

• Each fixture connection requires a vacuum interface valve, check valve, and full-port isolation valve. Typical plumbing fixture vacuum waste connections to the horizontal branches and mains (including water closets) should be 1-1/2" to maintain proper waste velocity.

• Use the Manning formula to keep pipe mains half full. Consider the probability of simultaneous use of fixtures during the pipe sizing process. If fire protection flows are connected to the system, consider omitting simultaneous flows from plumbing fixtures that will not be in use during a fire event. Be conservative, but do not overburden the system with unrealistic flow occurrences. Submit the layout to the manufacturer for review and comment.

• Develop piping details that will thoroughly indicate the requirements of the engineered system. Consideration should be given to double-line piping plans and elevation views of vacuum equipment in equipment rooms and any area where the layout may not be clear using single-line details/schematics. This is recommended because the installing contractor may not have previous experience with VPS installation requirements. Therefore, the design documents will most likely need to be developed beyond a typical level to properly detail the installation.

• To begin the equipment selection process, calculate the air flow requirements of the system. This load will be used to select the appropriate capacity and quantity of vacuum pumps. Consider redundancy and/or future capacity for system expansion. Coordinate with the manufacturer on the calculation process. Determine the time of day when the peak load begins and concludes. Determine the quantity of water closet activations to occur within the loading period.

• Prepare a calculation binder for code official final review. At a minimum, the binder should include complete sealed plans and details, air flow calculations, pipe sizing calculations, vacuum pump sizing calculations, discharge pump sizing calculations and collection tank sizing calculations.

• Well before the project bid period, provide an advanced project review with potential bidders. This additional step has the ability to eliminate undue concern about the installation of a VPS. Provide a complete overview of the design and address installation requirements. Most likely, bidders will have no previous experience with VPS installation and may be reluctant to get involved. This meeting will provide an opportunity to describe the similarities of vacuum to standard DWV systems as well as items that are unique. Allow attendees the opportunity to review the pre-final documents and encourage Q & A.

Regardless of any previous ideas or knowledge of VPS, consulting engineers and designers must consider this new technology. Make your own decision, consider the cost and remember the benefits may outweigh the risks and the gains may be too great to ignore. After all, that's how the West was won!

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