

MARCH 2010

# PS&D

PLUMBING SYSTEMS AND DESIGN



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## CASE STUDY

# Escaping the Shackles of Tradition— Green Plumbing Design for the Western Virginia Regional Jail

*if* Your career includes correctional facility design, you understand that plumbing system features in these types of buildings are fairly similar from project to project. They usually include centrally located mechanical rooms; cast iron, copper, or steel piping; and institutional stainless-steel plumbing fixtures that are piped through V-shaped or rear chases. Equipment must be reliable and heavy duty, include redundancy, and utilize damage-resistant construction materials. The general construction requires high-strength concrete, steel bars, steel doors, security cameras, and tamper-proof fasteners everywhere.

Veteran designers often say that you must think like an inmate to be an effective correctional systems designer. Over time, the correctional design elements and processes become quite familiar, which brings to mind the old adage, “If you’ve seen one, you’ve seen them all.” However, old adages don’t always hold true, and such was the case for the design of the Western Virginia Regional Jail (WVRJ).

### REIMBURSEMENT PROGRAM LEADS THE WAY TO SOLVING AN OVERCROWDING PROBLEM

The story of the WVRJ begins with a typical overcrowding problem in four Virginia jails located in Franklin, Montgomery, and Roanoke counties and the City of Salem. All were operating two to three times over their rated capacities. In 2005, the Western Virginia Regional Jail Authority (WVRJA) was formed by these localities to build a new jail under the state reimbursement program.<sup>1</sup> This program, administered by the Commonwealth of Virginia, provides relief for overcrowding by reimbursing 50 percent of qualified construction costs on any new jail built through the partnership of three or more localities. The new jail was planned

to provide additional capacity, act as a support center for the existing jails, and consolidate inmates, staff, and operating costs. The new facility would house post-trial inmates, inmates with medical problems or special needs, and those requiring increased supervision.<sup>2</sup>

The design for the 605-bed, windowless, precast concrete structure included provisions for future expansion to 1,600 beds. Initial construction capacity would house up to 805 inmates through double bunking. Utilities serving the jail, central mechanical space, and utility runouts for future expansion were included in the initial construction plan, allowing for future expansion to occur without disrupting existing jail operations. The facility was planned to accommodate an 80 percent male and 20 percent female population.

The 43-acre parcel of land (see Figure 1) selected by the WVRJA for the project site was challenging to develop from an engineering standpoint. The western Roanoke County, Virginia, location is near Dixie Caverns and immediately east of U.S. Route 460. The Norfolk Southern Railroad main line to Charlotte, North Carolina, lies at the southern edge of the site. The Roanoke River forms a horseshoe around the property’s west, north, and east boundaries, with the site perimeter falling in the 100-year flood plain.

As a result of engineering efforts to minimize the jail’s impact on the surrounding environment, the site was designed to produce less runoff into the Roanoke River than when it was undeveloped pastureland. Site development included a 1,500-foot roadway, a 12-inch water main, an 8-inch sanitary force main, and a 40-pound-per-square-inch (psi) natural gas service. Horizontal directional drilling was used to bore under the Roanoke River for placement of these utilities and to minimize any environmental impact caused by trenching.





Figure 1 Site of the Western Virginia Regional Jail



Figure 2 Overhead vacuum waste piping

by Mark Thayer, CPD

## PUBLIC OPPOSITION FADES AFTER THE ANNOUNCEMENT OF PLANS TO BUILD A LEED-CERTIFIED JAIL

The newly formed WVRJA contracted with the Roanoke, Virginia, office of AECOM Technology Corp. to serve as the primary architect/engineer of the new jail. AECOM would provide mechanical, electrical, and plumbing (MEP) and site civil engineering. Subconsultant Thompson and Litton located in Wise, Virginia, provided the conceptual design for the new facility, as well as full architectural design and structural engineering.

Unfortunately, as awareness of the WVRJA's plans for the new jail grew, public opposition also increased, so the WVRJA held meetings to allow the public to voice concerns and opposition. Reasons for the opposition varied significantly, but the most common concerns were environmentally based. Storm water runoff into the Roanoke River and the possible negative impact on the neighboring Dixie Caverns were the main concerns. AECOM addressed these concerns by ensuring that the jail would be located well above the 100-year flood plain; it would be positioned on the site so as to be mostly hidden from view; and special attention would be paid to storm water retention.

In August 2005, Roanoke County Administrator Elmer Hodge and Cabell Brand, a conservationist living in Salem, Virginia, proposed designing the new jail as a sustainable facility. After discussing the benefits of a green design, the WVRJA approved this initiative and approached AECOM about incorporating

green features into the design. The WVRJA desired a state-of-the-art facility that included sustainable features to obtain LEED certification. The LEED (Leadership in Energy and Environmental Design) green building rating system was developed by the U.S. Green Building Council and "provides building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operations, and maintenance solutions."<sup>3</sup>

Once the community was made aware of the WVRJA's plans to incorporate green features into the jail and that these features would reduce the jail's impact on the community and environment, opposition steadily decreased. Design objectives were modified to develop a LEED-certified facility that

would reduce its environmental impact on the surrounding community and reduce water consumption by using high-performing plumbing systems.

## POTENTIAL GREEN PLUMBING FEATURES

The design process began in September 2005. The designers prepared a list of possible features to include in the LEED design program, and upon completion of this effort, 48 possible features were listed for further consideration. Some of the plumbing items included are familiar in the green plumbing arena, including waterless urinals, sensor-controlled faucets, ultra-low-flow toilets, graywater collection for fixture flushing, rainwater collection, and solar panels for water heating. Some plumbing options are not



# CASE STUDY



Figure 3 Vacuum pumps



Figure 4 Plate frame heat exchanger near vacuum pump No. 1


 PROJECT: WESTERN VIRGINIA REGIONAL JAIL COMM. NO. 10075    DATE 1/12/2007    CAL. BY MDT    CKD. BY TZ / MPL TYPE Vacuum    PREL.    FINAL X    SHEET CONTENTS MAIN PIPE SIZING Group 10 - Areas C, G, K, L, & Lower F											
COLUMN 1				COLUMN 2				COLUMN 3			
FIXTURE TYPE / ITEM	FLOW RATE (gal/min)	TOTAL FLOW (gal/min)	MIN MAIN PIPE SIZE (in)	FIXTURE TYPE / ITEM	FLOW RATE (gal/min)	TOTAL FLOW (gal/min)	MIN MAIN PIPE SIZE (in)	FIXTURE TYPE / ITEM	FLOW RATE (gal/min)	TOTAL FLOW (gal/min)	MIN MAIN PIPE SIZE (in)
Area C				First Branch				WC-4			
SUMP-2	100	100.00	5	SUMP-2	100	100.00	5	WC-4	0.5	3.20	1.5
WC-7	6.4	106.40	5	WC-3	0.5	100.50	5	WC-3	0.5	4.20	1.5
WC-7	6.4	112.80	5	WC-3	0.5	101.00	5	WC-3	0.5	4.70	2
L-8	0.5	113.30	5	WC-3	0.5	101.50	5	WC-3	0.5	5.20	2
S-1	2.2	115.50	5	WC-3	0.5	102.00	5	Back To Main			
L-8	0.5	116.00	5	Back To Main				238.00			
WC-7	6.4	122.40	6	182.80			6	Middle G Branch			
WC-3	0.5	122.90	6	Second Branch				WC-2	0.5	0.50	1.5
WC-3	0.5	123.40	6	WC-3	0.5	0.50	1.5	MR-2	2.5	3.00	1.5
WC-3	0.5	123.90	6	WC-3	0.5	1.00	1.5	L-1	0.5	3.50	1.5
WC-3	0.5	124.40	6	WC-3	0.5	1.50	1.5	SUMP-1	50	53.50	6
WC-3	0.5	124.90	6	WC-3	0.5	2.00	1.5	S-1	2.2	55.70	5
WC-3	0.5	125.40	6	Third Branch				S-1	2.2	57.90	5
WC-8	6.4	131.80	6	WC-2	0.5	0.50	1.5	S-1	2.2	60.10	5
WC-8	6.4	138.20	6	L-1	0.5	1.00	1.5	S-1	2.2	62.30	5
WC-3	0.5	138.7	6	MR-2	2.5	3.50	1.5	S-1	2.2	64.50	5
WC-4	0.5	139.20	6	S-1	2.2	5.70	2	S-1	2.2	66.70	5
WC-3	0.5	139.70	6	WC-4	0.5	6.20	2	Back To Main			
WC-3	0.5	140.20	6	WC-3	0.5	6.70	2	254.70			
WC-3	0.5	140.70	6	WC-3	0.5	7.20	2	Upper G Branch			
WC-3	0.5	141.20	6	WC-3	0.5	7.70	2	WC-2	0.5	0.50	1.5
WC-3	0.5	141.70	6	Back To Main				L-1	0.5	1.00	1.5
WC-4	0.5	142.20	6	192.50				L-4	0.5	1.50	1.5

Figure 5 Calculation spreadsheet used to size the vacuum piping

as familiar, including biomass stoker boilers for water heating, composting toilets, a vacuum plumbing system, electronic water controls for fixtures, and heat recovery from vacuum pumps for preheating domestic hot water.

Interestingly, during the vetting process the vacuum plumbing system was placed near the bottom of the list under "Miscellaneous Items" and received little evaluation. However, as the 48 items were analyzed further, interest grew in the vacuum plumbing system because of the possibility to obtain multiple LEED points through only a moderate construction cost increase. The team's conclusion included three major benefits that 1) vacuum plumbing would be far more beneficial from an operating cost standpoint due to the water savings it provided over traditional gravity-based sanitary piping; 2) vacuum plumbing had no negative impact on the construction schedule

as the piping would be installed simultaneously with other overhead systems (see Figure 2); and 3) this system would allow the jail staff to better prevent inmates from disrupting operations by toilet fixture abuse or contraband sharing.

After thorough analysis by the design team and the WVRJA, 22 final sustainable design features ultimately emerged. The list of green plumbing features included vacuum plumbing, electronic water controls on all plumbing fixtures, siphonic roof drainage with underground rainwater collection for exclusive use in laundry operations, sensor-controlled faucets in public and administration toilet areas, and heat

recovery from the vacuum pumps (see Figure 3) for preheating domestic hot water (see Figure 4).

## THE FIRST JAIL PROJECT ON THE EAST COAST TO USE VACUUM PLUMBING

After significant independent research of existing vacuum system installations, the WVRJA determined that AcornVac would provide the vacuum system via sole-source delivery. They also would provide all plumbing fixtures and electronic water controls through their parent company, Acorn Engineering Co. Ultimately, AcornVac provided collaboration, document review, and analytical support during the entire design process. They were very responsive to the project's unique nature and design schedule.

The vacuum plumbing system was attractive to the WVRJA because of the 0.5-gallon-per-flush (gpf) vacuum toilets and

urinals as compared to regular toilets and urinals, which use 1.6 gpf and 1 gpf respectively. Also, with the addition of the electronic flush valve control system, jail staff could remotely monitor and control the quantity of flushes per cell in the facility. Conventional flush valves have no such control capability, and the ultimate water consumption is dictated by facility occupants, typically amounting to as much as 25 flushes per day. By providing this level of control over inmate activity and reducing toilet flushing frequency, additional significant water savings were possible.

As the vacuum system design began, several obstacles had to be addressed, including the lack of a recognized vacuum design standard, inapplicability of the Hunter's curve for system sizing, conflicting requirements for piping materials, and concern about how to obtain authority having jurisdiction (AHJ) acceptance. The design involved a carefully developed implementation plan for the vacuum plumbing system. Objectives included a well-engineered design, complete system by-in from the WVRJA, design support and system commissioning from AcornVac, and proper allowances in the design for system maintenance.

The vacuum plumbing design involved reworking Hunter's supply sizing curve to take advantage of the 0.5-gpf water demand. This task applied a ratio using the U.S. Environmental Protection Agency's 1992 Energy Policy Act flush rate over the vacuum flush rate to the standard 10 supply fixture units (SFUs) for flush valves, which resulted in an SFU value of 4. Dr. Hunter's probabilistic recommendation for simultaneous use of fixtures was not altered.

The piping material selected for the vacuum system piping was Schedule 10 stainless steel pipe with mechanical grooved couplings and flush seal gaskets. This decision satisfied Virginia Board of Corrections standards, which do not allow any type of plastic piping to be used within the secure perimeter of a corrections facility.<sup>4</sup> This decision also accommodated the full pressure capability of the vacuum plumbing system, which is 1 bar (760 mm/Hg). Calculation spreadsheets were established to size the vacuum piping in the facility using the Manning equation (see Figure 5). A value of 0.012 was used as the coefficient of roughness of the stainless steel piping.

All plumbing fixtures within the facility were connected to the vacuum plumbing system, except those in the kitchen and laundry. Fixtures in these areas were not connected to the vacuum plumbing system because of the possibility of additional maintenance of vacuum components in the grease and high-temperature waste piping.

#### RAINWATER MANAGEMENT SYSTEMS JOINS THE DESIGN TEAM

Unlike the vacuum plumbing system, siphonic roof drainage and rainwater harvesting were always at or near the top of the green building features desired by the WVRJA. As the design program continued, subconsultant Rainwater Management Systems of Salem, Virginia, developed the design of these systems. The team determined that nearly the entire roof surface of 261,144 square feet

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Figure 6 Underground storm water storage tanks



Figure 7 Rainwater harvesting system

## CASE STUDY

would drain via the siphonic roof drain system. The water would be collected in four 30,000-gallon underground storm water capture tanks (see Figure 6), pumped to a filtration system in the mechanical room, and delivered exclusively to the laundry for clothes-washing operations. Potable water also was connected to the system for makeup during low water levels in the tanks.

The tanks were sized based on a peak laundry demand of 22,000 gallons per day (gpd) and an average rainfall event of 0.1164 inch per day over the roof surface, which would yield 19,000 gpd. A 3/4-inch rainfall event would essentially fill the 120,000-gallon collection system. A 62 percent diversity factor was used to address drought conditions and spillage when the collection tanks are full.<sup>5</sup> This system is expected to pay for itself in three years and reduce annual operating costs every subsequent year.

### APPROVAL OF ENGINEERED SYSTEMS OBTAINED FROM THE AUTHORITY HAVING JURISDICTION

Early in the design process, the design team coordinated all engineered systems planned for use in the jail with the Roanoke County Building Department, which acted as the AHJ over the construction. In March 2006, contact was made with the AHJ official assigned to review the plans for the facility. A tentative meeting date was discussed for presenting the jail's proposed engineered systems, including siphonic roof drainage, rainwater harvesting, and the vacuum plumbing system. Hoping to acquire formal AHJ approval of the systems, a presentation was made on the engineered system design approaches. The following day, the AHJ confirmed that the engineered systems would be considered an alternative method of performance in accordance with the Virginia Uniform Statewide Building Code, Section 112.2.<sup>6</sup>

### WILL A REPUTABLE MECHANICAL CONTRACTOR BID ON THE PROJECT?

Due to the unique nature of the jail's systems, installation experience was essentially nonexistent in the region or within a reasonable travel distance. Toward the end of the design process, research began to locate quality MEP subcontractors, primarily based in Virginia, to discuss the unusual MEP features such as siphonic roof drains, rainwater collection, and vacuum plumbing that would be incorporated in the design of the WVRJ.

A mechanical and plumbing systems overview meeting was held to inform possible subcontractors about the project. The meeting was intended to educate and inform potential subcontractors about specific operational features of the engineered systems. Eleven MEP subcontractors were invited to the meeting to discuss the jail project and schedule, and five attended.

Drawings and specifications of the "unusual" plumbing systems were provided for their review. AcornVac attended the meeting to provide continued hands-on support and an overview of the vacuum system's operation, as well as to answer any questions.

### CONCLUSIONS FROM THE PROJECT'S LEED SCORECARD

The design incorporated numerous green features that resulted in 29 credits for LEED certification, with only 26 credits required for a Certified rating. Of those 29 credits, 16 design credits were approved, two design credits were denied, and 11 construction credits currently are under review. The WVRJ is expected to receive LEED certification, making the regional jail the first LEED-certified jail in Virginia and one of the first in the United States.

When the LEED scorecard was completed, the total water savings provided by the jail's systems totaled nearly 11 million gallons of water per year. LEED water-efficiency credits yielded a 62.4 percent water reduction over the facility's baseline, which equates to a savings of more than 6.1 million gallons of water per year. This reduction was due largely to the vacuum plumbing system. With this exemplary performance, a LEED innovative design (ID) credit was achieved. The rainwater harvesting system (see Figure 7) also provided an ID credit due to the laundry process use of rainwater, which saved an additional water usage of nearly 4.3 million gallons per year.

### HIGH PERFORMING CONSTRUCTION TEAM SELECTED

Howard Shockey and Sons Inc. of Winchester, Virginia, was selected as general contractor, and construction began in April 2007. The family-owned business provides construction services for new and renovated structures and has delivered a number of justice and corrections projects throughout the Mid-Atlantic region. The WVRJ opened in April 2009 after a 24-month, \$78.5-million construction process.

Southern Air of Lynchburg, Virginia, provided mechanical and plumbing subcontracting. Southern Air specializes in the installation and service of HVAC, plumbing, piping, and electrical systems in Virginia, North Carolina, and West Virginia. They possess a strong reputation and commitment to quality installations. With

the plumbing portion of the project being somewhat unusual and innovative, a firm with the desire to provide exceptional performance was essential.

#### DESIGN TEAM'S SATISFACTION EQUALS A HAPPY CLIENT

The completed WVRJ was dedicated during a formal public ceremony on March 6, 2009, and the lobby was packed with public officials and interested citizens. The WVRJ is a unique facility that stands as a monument to the benefits of high-tech plumbing innovation. Superintendent of the WVRJ Charlie Poff stated that he is "completely satisfied with the regional jail's design with its high level of functionality, which resulted from AECOM's willingness to work closely with representatives of the Western Virginia Regional Jail Authority, the professional corrections officers managing this process for the owner, and Virginia Department of Corrections staff throughout the design process. We are very pleased with the facility's multiple environmental or 'green' features and how they were incorporated in the design without causing any delays in the project." He went on to say, "We find that the new regional jail functions as it was designed to do. The building's collaborative design and the sustainability features that were included in the design are a win-win for us and will be for many years to come."

#### HONOR AWARD RECEIVED FOR VACUUM SYSTEM DESIGN

This project provided an opportunity to implement innovative plumbing solutions for a unique client. The design and construction process is now complete, and it will be remembered as one of the most unique projects of my career. In December 2009, the American Council of Engineering Companies (ACEC) awarded AECOM with a 2009 Engineering Excellence Honor Award for the design of the vacuum plumbing system at the WVRJ. The award was accepted at the ACEC 2010 Gala in Richmond, Virginia, in February. **PSD**

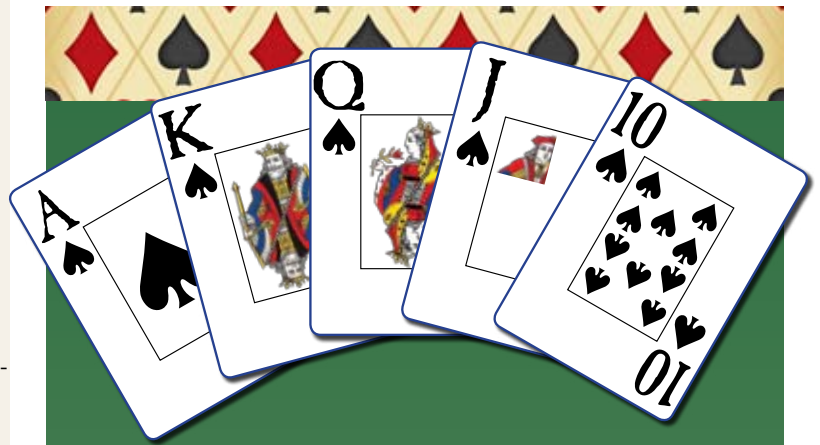
#### PHOTO CREDIT

All photos in this article were taken by Richard Boyd.

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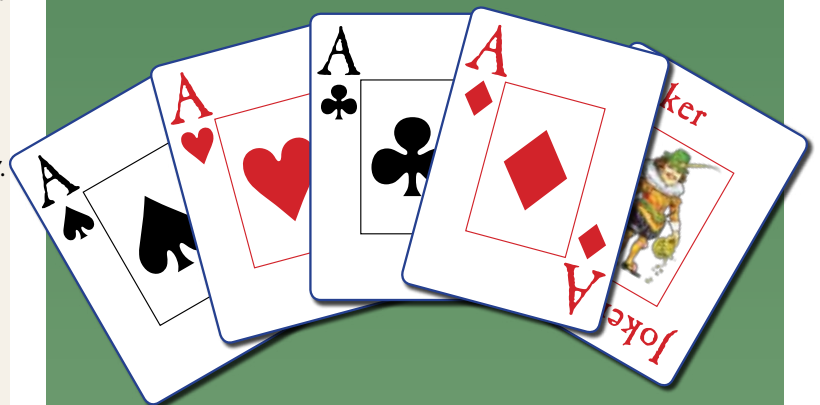
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