ZDS 25th Anniversary

DESIGN/CONSULTING SERVICES

Expression of Interest to Provide Third Party Peer Review Engineering Services for Renovations on Building Four

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WV PURCHASING DIVISION

June 24, 2020
CEOI 0211 GSD2000000005

MECHANICAL / ELECTRICAL / IAQ / ENERGY / COMMISSIONING

ZDS Design/Consulting Services 25th Anniversary
281 Smiley Drive, St. Albans, WV 25177
Phone: (304) 755-0075 / www.ZDSDesign.com

of the Tri-State Region

MECHANICAL • ELECTRICAL • INDOOR AIR QUALITY • ENERGY • COMMISSIONING • FORENSIC

June 24, 2020

WV Department of Administration
Purchasing Division
2019 Washington Street, East
Charleston, West Virginia 25305-0130

ZDS has enjoyed working with hundreds of facilities throughout the State and hope to have the opportunity to provide *Third-Party Peer Review Services on the Building 4 Renovations* for the ***WV Department of Administration.***

ZDS Design/Consulting Services and **Facility Dynamics Engineering (FDE)** have teamed on both design, peer review and Commissioning projects for over 25 years and we believe that our experience and knowledge will be an excellent fit for the proposed project. Our team has provided professional mechanical, electrical, plumbing engineering consulting and peer review/commissioning services for facilities across the country. Our decades of experience for the proposed staff give the strength and depth important for the project needs. **FDE** is ranked as the 5th largest MEP Peer Review/Commissioning firm in the United States by Consulting-Specifying Engineer and a recognized leader in the industry.

ZDS has teamed with Clarksburg based Architectural Firm, **WYK Associates, Inc.** for several previous projects and will utilize their services as necessary for the peer review of the elevator and associated conveyance systems for the ***Building 4 Renovations Project.***

The total number of Design/Commissioning projects exceeds 3,000 when looking at the work of our companies with the project costs ranging from less than $10 million to over $1 billion. Our professionals are dedicated to performing quality services while considering our clients' needs, scheduling and budgets. Our Team carry liability insurance coverage in compliance with local and state laws and proof of Insurance can be provided as necessary to fulfill the requirements of this Project.

The Team's combined Services encompass many projects and complex systems including High Performance and LEED projects. Some recent Peer Review/Commissioning projects include the $43 million LEED Silver Certified maintenance hangar/fuel cell facility for the West Virginia Air National Guard at Yeager Airport, a LEED Gold Certified Research facility for Harvard University and a $45 million addition and renovations to William R. Sharpe, Jr. Hospital for the West Virginia Department of Health and Human Resources, Weston, West Virginia. We also provide those services for many schools, government agencies and Universities.

FDE has provided services on over two thousand commissioning projects, including projects of $1 billion and more in construction value. They employ over 60 Engineers/Commissioning specialists and can provide a valuable role in teaming with **ZDS**. **FDE** provided commissioning services for the Strathmore Concert Hall, North Bethesda, Maryland, $40 million LEED Gold Certified VCU Monroe Park Campus Cary Street Gym in Richmond Virginia, University of Mary Washington Anderson Center located in Fredericksburg, Virginia and the 180,000 sq. ft. Pauley Pavilion renovation with a 60,000 sq. ft. expansion for the University of California, Los Angeles, California which is expected to receive a LEED Certification.

WYK Associates, Inc., WV's oldest Architectural firm has experience on nearly 40 elevator projects in recent years and many more over its 120-year history. Projects have entailed adding new elevator shafts and elevators within existing building envelopes of historic structures, and upgrades/replacements to/of existing elevators. Some include constructing new shafts on the exterior of buildings by being sensitive to the building's original architecture and new elevators in new construction. Some recent challenges overcome include a car with a door in the front and the side to fit a project that involved a custom designed corner post hydraulic elevator. Some current projects include United Hospital Center and the 50-year old, ten story Koupal Towers located in Clarksburg, WV for the Clarksburg-Harrison Regional Housing Authority.

ZDS Design/Consulting Services Team have registered professionals in all the required disciplines to effectively execute the requirements of the project, including:

- **Commissioning/Energy Engineering**
- **Electrical Engineers**
- **HVAC Engineers**
- **Elevator conveyance specialists**

Technical Peer review will provide an independent and objective technical review of the design of the project, or a part thereof, conducted at specified stages of design completion by one or more qualified professionals for the purpose of enhancing the quality of the design. A peer review may include specific focus areas that are of expressed concern. It may also include a constructability review, which is the review of effective and timely integration of construction knowledge into the conceptual planning, design, construction, and field operation of a project to achieve project objectives efficiently and accurately at the most cost-effective levels to reduce or prevent errors, delays, and cost overruns. Constructability reviews will cover installation concerns, proper sequence and scope where construction phasing is described in contract documents and will look at the detail in specifying integration between systems. One example of an aspect that is important to review is the coordination of documents covering the fire alarm and security systems that will interface with an elevator for high rise facilities that would likely apply to Building #4. Another example is a smoke control system that has interfaces between HVAC systems, their dedicated controls and the fire alarm system, which most often is used to initiate and sometimes operate the smoke control system.

The proposed team of **ZDS**, **FDE** and **WYK** is qualified to provide peer reviews and has the experience in all the areas and disciplines necessary to deliver the services wanted on this

Project. This includes engineering design, construction, and commissioning of the systems within the scope. It is important that a peer review is clearly defined, stating goals and limitations. For example, a focused peer review will evaluate the adequacy of the thermal capacity of an HVAC system and will state the method by which it is verified. In the case of the focused review, there will likely be complete review or duplication of the engineering calculations, including assumptions. A more general approach will rely on the reviewer's own experience in HVAC design of similar systems and applications, or on industry 'rules of thumb' for typical capacity requirements. In either case, the methodology must be determined and stated early in the process to adequately provide the Client with the services and results they seek. An example of a focused peer review is included as an Appendix.

The Team has the years of experience and best expertise to provide the services to fulfill your specific project's needs. Our Team's professional services efforts have been extremely effective in the past by acting in our clients' behalf to help bridge the new technologies and management methods into actual operating practices that have saved our clients substantial funds in construction and operating costs. We pride ourselves on being viewed as an extension to the client's staff and successfully incorporating pertinent information about their facility into any proposed solution. Please feel free to contact any of our references about our work. Our Team has an excellent track record and are ready and willing to start on your project. If there are any questions, please do not hesitate to call.

Sincerely,

Todd A. Zachwieja, P.E., CEM, LEED AP
Principal, Chief Executive Officer

2.1 GOAL/OBJECTIVE 1 Given the scope of renovations to occur, the goal of the Agency is to have a Third-Party Peer Review firm/team that is experienced in the specific disciplines of design required to fully renovate the building and its systems.

Within their proposals, interested firms should provide information regarding its employees, such as staff qualifications and experience in completing Third Party Peer Review(s) of similar full-building renovation projects. Specifically, the proposals should indicate that the Third-Party Peer Review firm/team has at least fifteen (15) years' experience in each of the following disciples: mechanical engineering, elevator and lift conveyances, building commissioning, and cost estimating.

RESPONSE ***Refer to Sections III and IV*** *for information regarding the Teams' specific expertise, diversity of projects, and the many cumulative years of professional engineering services experience. ZDS's team have over twenty-five (25) years' experience performing mechanical engineering, elevator and lift conveyances, building commissioning and cost estimating. Clients include WV Capitol Complex (GSD), Marshall University, University of Charleston, WVU, Harvard University, Laidley Towers, General Motors, WV Air National Guard, WV Dept of Transportation, WVDHHR, many schools and higher education facilities.*

2.2 THIRD PARTY PEER REVIEW The goal of the Agency is to have a Third Party Peer Review performed at various design phase intervals, likely first at the completion of mechanical systems conceptual design phase, at the 50% and/or 90% construction documents phase, and then provide review and comments on the HVAC and Elevator commissioning specifications.

RESPONSE *Peer review is an integral part of Commissioning services which ZDS's team has been performing for over twenty-five (25) years. ZDS's forensic engineering experience where construction issues need solved independent of the original designers is invaluable during the third-party peer review process. Our team's practical in-depth analysis and hands-on experience will enhance the planning, design and construction phases. The Team has extensive experience in review of other design professionals' evaluation reports, planning and design of a multitude of building systems including, but not limited to, HVAC, Electrical, Plumbing, Fire Protection and specialty equipment/systems such as elevators and their interconnection with other systems. We will request electronic comprehensive sharing of all planning and design documents prepared by the A/E for the renovations at Building 4 for our review and assessment. Our Team will prepare comments and recommended changes for consideration in a written report submitted to the Client at the selected intervals throughout the design phases. The commentary identifies ideas for enhancements to the design documents with explanations on why it improves the final results recognizing the Agency will be operating the facility for many decades.*

Our strengths in commissioning add value into the design process to incorporate maintenance and operation issues including serviceability from our hands-on experience in operating facilities. Our strengths in high performance design and ASHRAE standards including Indoor Environmental Quality and energy efficiency enhance the review process. Our goal is to provide a collaborative effort to be part of the overall project team and foster dialogue and effective communications that meet the overall project goals and objectives.

The State of WV adopted ASHRAE 90.1-2010 Energy Codes and our team has been an instrumental part of ASHRAE and helped teach the state energy codes while assisting governmental agencies meet these codes. We also understand renovation projects have their unique challenges and can assist in balancing energy efficiency with long term benefit and the initial costs.

2.3 WRITTEN REPORTS OF THIRD-PARTY PEER REVIEW

The goal of the Agency is to have written reports of the periodic reviews submitted for Agency review.

Within their proposals, interested firms should document their Past Performance in providing written reports of their performed reviews. Providing excerpts of sample past reports would be preferred. Interested firms should indicate how they intend to provide such written reports upon the completion of the various suggested phases of review for this project.

RESPONSE

Our Team has provided hundreds of written reports based on a full spectrum of building types, occupancies and infrastructure systems. These reports include results of intensive field investigations, recommended upgrades for energy efficiency and occupant comfort, construction cost estimating, Code compliance, addressing construction deficiency issues and general summaries of facility evaluation. We have performed peer reviews of other design professionals work and have been involved in commissioning services for over twenty-five (25) years addressing the challenges of sustainable, efficient facility operation. Our team's data base of projects includes thousands of projects with access to over 60 engineers for a wealth of experience beyond the team presented in this RFQ.

It is important that a peer review is clearly defined, stating goals and limitations. For example, a focused peer review will evaluate the adequacy of the thermal capacity of an HVAC system and will state the method by which it is verified. In the case of the focused review, there will likely be complete review or duplication of the engineering calculations, including assumptions. A more general approach will rely on the reviewer's own experience in HVAC design of similar systems and applications, or on industry 'rules of thumb' for typical capacity requirements. In either case, the methodology must be determined and stated early in the process to adequately provide the Client with the services and results they seek. An example of a focused peer review is included as an Appendix .

2.4 COLLABORATIVE THIRD PARTY PEER REVIEW MEETINGS

The goal of the Agency is to have the Third-Party Peer Review firm/team participate in collaborative meetings with the Architect-of-Record, the Agency, and other potential stakeholders to coordinate and discuss the completed Reviews.

Within their proposals, interested firms should document their Past Performance on projects in which such collaborative meetings occurred.

RESPONSE

Throughout our years in the business the proposed Team for this Project has collaborated with many different key players and stakeholders on a multitude of various projects. Our principle goals have always been to prioritize the Client's wants, budget and schedule keeping their best interests in mind. We have achieved this through close communications and meetings with the Client's personnel, Architects, Engineers, Contractors and State Agencies, including the WV State Fire Marshal and other stakeholders.

Effective communications and prompt response to the Owner's needs are why past clients state "ZDS is an extension of our staff. They are great planners and designers! They help us make the best decisions for the long term. We would recommend them to anyone!" - Greg Nicholson, former Chief Operations Officer DHHR

2.5 CONSTRUCTION ADMINISTRATION PEER REVIEW

An optional goal of the Agency may be to require the Third-Party Peer Review firm/team perform review of the administration of the construction by the Architect-of-Record.

Within their proposals, interested firms should document their Past Performance in providing Third Party Peer Review services during the construction administration phase of building renovation projects. Proposals should also include documentation to the firm/team's approach to providing such services on this project.

RESPONSE

Our Team members average over 25 years' experience in the construction phases of projects covering many aspects of a facility's infrastructure and systems. Our involvement has been on Mechanical, Electrical, Plumbing and Peer Review/Commission systems with an emphasis on energy efficiency. Our experience includes peer review of other professional's design in new construction and major renovations as well as assisting the Client during the Construction Administration phase as a third-party observer. Our vast experience in Commissioning services will provide the Agency with the oversight necessary to result in a successful Project. We will request that our Team receive reports, communications and other documents generated by the A/E, Agency and contractors during the construction process so that we may better serve the Agency's needs. Site visits to observe the work will be performed as necessary to maintain a good understanding of the progress and reports of any significance issues will be prepared and shared with the Agency and others as directed.

Recommend incorporating Commissioning services into the construction/bidding documents in compliance with ASHRAE 90.1 Energy Codes adopted by the state. Commissioning services can be provided by our Team as part of the overall efforts during the construction period.

FIRM OVERVIEW

ZDS DESIGN/CONSULTING SERVICES 25th Anniversary

Founded in 1994, celebrating 25 years!

ZDS Design/Consulting Services is a three-generation family owned MEP/Commissioning Engineering Firm located near Charleston, West Virginia. ZDS provides comprehensive professional services for Master Planning/ Feasibility Studies, HVAC, Plumbing, Electrical, Indoor Environmental Quality, Energy Engineering, Forensic Engineering and Commissioning. ZDS has extensive proven high performance building design experience for commercial, governmental, educational facilities, and healthcare experience in 24 states across the country, the State of West Virginia, local government and Federal agencies. Specializing in renovation projects with ***proven results of from 30% to over 50% reduction in energy/ operating costs*** earning Energy Star Certification and EPAct qualified on government renovation projects!

- Mechanical
- Electrical
- Plumbing
- Forensic
- Energy
- Commissioning
- Indoor Environmental Quality (IAQ/IEQ)
- High Performance Sustainable Buildings

The ZDS team is made up of seasoned professionals who have dedicated their careers to engineering design excellence and quality. A strong foundation in Performance Contracting is incorporated into design and commissioning with an appreciation for the maintenance staff to be able to operate the systems over the life of the facility. We pride ourselves in having the most up to date state of the art technology to provide our clients the very best possible services. We offer comprehensive practical solutions to our clients with proven World Class results.

COMPANY LEGAL NAME

ZDS Limited Liability Company
dba ZDS Design/Consulting Services

OFFICE LOCATION

281 Smiley Dr., St. Albans, WV 25177

FOUNDERS

Todd A. Zachwieja, P.E., C.E.O.

Lori L. Zachwieja, C.P.A., C.F.O.

Daniel H. Kim, Ph.D.

Building EQ CERTIFIED PROVIDER

ENERGY STAR


ASHRAE Insights

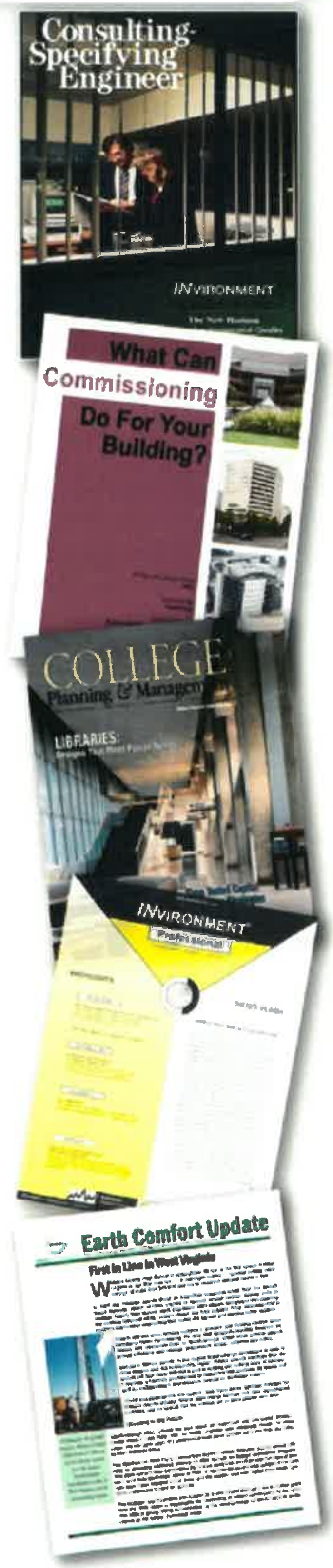
Three Generations of Service to ASHRAE

"Family Owned & Operated Engineering Firm providing Professional Design Services for over 25 years"

FIRM OVERVIEW

ZDS 25th Anniversary
DESIGN/CONSULTING SERVICES

ZDS provides forensic engineering services for the Indoor Environmental Quality (IEQ) including "Indoor Air Quality (IAQ). These services include: strategic planning for renovation and new construction projects; technical research and writing; specialized applications software development; corporate and professional training programs; publications support and fulfillment; and site-specific engineering and scientific consultation. Todd Zachwieja, ZDS Principal, is contributing editor for the following publications:



- Technical Review Panel for the publication of the *INvironment™ Handbook of Building Management and Indoor Air Quality*, by Chelsea Group and published for Powers Educational Services
- Technical Review Panel for the quarterly publication of the *INvironment™ Newsletter*, by Chelsea Group for Powers Educational Services
- *Ventilation for a Quality Dining Experience: A Technical Bulletin for Restaurant Owners and Managers*
- *The New Horizon: Indoor Environmental Quality*, published as a supplement to an issue of *Consulting-Specifying Engineer* magazine, a trade magazine distributed to roughly 50,000 engineers
- Editorial Advisory Board member reviewing the articles of the monthly publication *INvironment™ Professional*

ZDS provides Indoor Air Quality (IAQ) services for major corporations, government organizations and property owners to resolve their specific facility problems:

- ***Resolve "sick building syndrome"***
- ***Identify solutions to building-related illnesses due to extensive biological contamination***
- ***Develop solutions for HVAC systems, temperature controls, equipment, operating and maintenance practices for indoor air quality***
- ***Commission new and renovated facilities to minimize or eliminate IAQ issues before problems arise***
- ***Develop and establish master plans as well as conduct training seminars for IAQ of schools and commercial buildings***

As one of the nation's leaders in Indoor Air Quality (IAQ), ZDS provides sophisticated technical expertise that enables our client to be proactive in solving and preventing indoor environmental problems.

FIRM OVERVIEW

Facility Dynamics Engineering

COLLABORATION. INNOVATION. PERSISTENCE.

FOUNDERS
Lon Brightbill, PE
Jay Santos, PE

WHEN WE OPENED
1989

WHERE WE ARE
Corporate
6760 Alexander Bell Drive
Suite 200
Columbia, MD 21046
410.290.0900

Local Presence in 19 states, 50 cities

WHAT WE DO
- Building Commissioning
- Controls Engineering
- Remedial Engineering
- Training
- Fault Detection Diagnostics

CONTACT
Jay Santos, PE
Principal, Co-Founder
410.290.0900
jays@facilitydynamics.com

www.facilitydynamics.com

FDE was founded in 1989 to bridge the gap between construction and facility operation and to address the challenges of sustainable efficient facility operation.

We have maintained that focus with our team of senior professionals who have extensive experience in systems design, construction, training, and operation of mechanical, electrical, and building controls/automation systems.

Our culture is to foster collaboration and inject our unique expertise to help the project team deliver successful facilities. As pioneers in the building commissioning industry, we have an unparalleled resume of successful highly complex facilities.

THE TEAM
We believe, and our actions and history show, that it is essential for the commissioning engineer to be a collaborative and constructive team member. Our comprehensive approach combines analysis with state-of-the-art software to create a thorough, efficient, and superior building commissioning process.

Our highly skilled staff have complementary expertise in mechanical and electrical systems design, HVAC controls, electrical testing, systems balancing, training, operations and maintenance, and remedial system analysis. We believe in a process that actively includes our engineers and technicians.

"WE ARE GLAD FDE IS HERE"
FDE embraces the attitude that the primary goal of commissioning is to deliver:

- High performance and properly operating facility to the Owner
- Well-trained Operations and Maintenance staff
- High quality and continually useful documentation of the facility and of the commissioning process.

Further, we approach our commissioning activities with the highest respect for the various parties in the design and construction processes and their roles. The words 'we are glad FDE is here' is heard often from contractors and owners alike, and we take great pride in compliments like this.

#5 by CONSULTING-SPECIFYING ENGINEER
Facility Dynamics Engineering was recently ranked the #5 MEP Commissioning firm in the United States. Compiled from revenue, performance, and percentage of work committed to the discipline, Facility Dynamics is a leader in the industry with its significant presence in the buildings and facilities landscape.

COURTHOUSES and JUDICIAL CENTERS

- Colonial Heights Courthouse, *Richmond, VA*
- General Services Administration, Fresno Courthouse
  Fresno, CA
- General Services Administration, San Diego Federal Courthouse Annex (Schwartz Federal Building)
  San Diego, CA
- General Services Administration, Seattle Courthouse
  HVAC Improvements
  Seattle, WA
- Howard County Courthouse, Columbia, MD
- Kent County Courthouse, *Kent County, DE*
- Los Angeles Federal Courthouse Review
  Los Angeles, CA
- Montgomery County Judicial Center Annex,
  Gaithersburg, MD
- New Castle County Courthouse, Retro-Cx
  Wilmington, DE

OTHER PUBLIC SAFETY AND MUNICIPAL FACILITIES

- Chesterfield County Jail Annex, *Richmond, VA*
- Chesterfield County Police Headquarters Renovation
  Richmond, VA
- Clarence E. Lightner Public Safety Center,
  Raleigh, NC
- County of Henrico,
  Juvenile Detention Center & East Jail & Regional Jail,
  Richmond, VA
- DC Government Unified Community Center
  Washington, DC
- Delaware New Castle County Detention Center,
  Wilmington, DE
- Delaware Public Safety Building E Wing
- Delaware State Police Headquarters Complex,
  Dover, DE
- Los Angeles Police Department Headquarters
  Los Angeles, CA
- Prince George's County District VII Police Station,
  Washington, MD
- Montgomery County Public Safety Training Academy & Public Safety Headquarters,
  Gaithersburg, MD
- New Stevenson House Detention Center, *Milford, DE*
- UNC School of the Arts Police Operations Center
  Winston-Salem, NC

FIRM OVERVIEW

Company Information

Identity · Project Philosophy · Project Management

WYK ASSOCIATES, INC.
ARCHITECTURE•PLANNING

www.wykarchitects.com

Our Identity

Who we are

WYK Associates, Inc. is a full service architectural and planning firm serving a wide variety of commercial, religious, educational, civic and industrial clientele.

WYK Associates, Inc. was established in 1900 by Edward J. Wood. Our archives are filled with a century's worth of historic work. From this, many predecessors who have carried the torch of the firm through the last century.

Wood's grandfather's firm had roots in North Central West Virginia dating back to the early twentieth century. William Yoke, Jr. and Howard Kelley partnered with Mr. Wood in 1974 to form WYK Associates, Inc.

Mr. James Swiger joined the firm in 2005 and became a principal and vice president in 2008. In 2010, Mr. James Swiger assumed sole owner of WYK Associates, Inc.

Project Philosophy

Our process at work

COMMUNICATION & TEAMWORK are our guide words for each project. Our client's requirements for quality, service and value are the driving force behind each decision.

Through collaboration with engineering consultants we address the needs and schedule requirements of each client.

We provide thorough planning in all areas of each project to fit the individual requirements for a positive impact on both the natural and built environments. Energy conservation and product safety are very important concerns.

Project Management

How we create excellence

We carefully evaluate the client's program, design concerns, budget, funding sources, and other available data to assure a clear understanding of each project.

We incorporate input from our client and consultants to establish the budget and schedule. These facets are updated during each stage of project development to ensure our client's parameters are met.

WYK's principals engage and manage the entire project team, from concept through occupancy. WYK Associates, Inc. has an outstanding reputation for providing construction administration services along with maintaining an excellent rapport with contractors.

> "Our building stands as a tribute to you and your firm for a job well done."
>
> -Charles A. Feathers, Chief Bridgeport Fire Department, Retired

FIRM OVERVIEW

WYK ASSOCIATES, INC.
ARCHITECTURE•PLANNING

Company Information

Identity · Project Philosophy · Project Management

Architecture

Contact Information

WYK Associates, Inc.
205 Washington Avenue
Clarksburg, WV 26301

304-624-6326

304-677-3373 Cell

304-623-9858 Fax

www.wykarchitects.com

Summary

Established as a full service architecture firm in 1900, then named Edward J. Wood Architect, WYK Associates, Inc. has been located in Clarksburg for 119 years. Through innovative and thoughtful responses to the unique issues of each project, our goal is to create places that fit the needs and desires of those who use them.

Our team approach integrates the collaborative strengths of each member to produce a solution of balance between design quality, schedule and budget. We have always considered sustainability, the built environment, and quality of life long before the public began to focus on its benefits. We take seriously the responsibility of designs and solutions to be cost effective and operate efficiently throughout the building's lifecycle.

Relevant Project Experience:

West Virginia Folklife Center, Fairmont State University

Central Fire Station, Clarksburg, WV

Circleville School, Pendleton County, West Virginia

Pocahontas County Courthouse, Marlinton, WV

Barbour County Courthouse, Philippi, WV

Gassaway Depot, Gassaway, WV

Immaculate Conception Parish Center, Clarksburg, WV

Jackson Square, Clarksburg, WV

Robinson Grand Performing Arts Center, Clarksburg, WV

Robinson Grand Performing Arts Center

West Virginia Folklife Center

Central Fire Station

Memberships

AIA The American Institute of Architects

AIA West Virginia

NCARB

NATIONAL TRUST for HISTORIC PRESERVATION

FIRM OVERVIEW

WYK ASSOCIATES, INC.
ARCHITECTURE • PLANNING

Company Information

Identity · Project Philosophy · Project Management

3D Laser Scanning / 3D Modeling / 3D Printing

WYK Associates, Inc. welcomed the New Year by taking a leap of progress in architectural design. By acquiring a color 3D printer, the Clarksburg architectural-planning firm puts themselves on the map as an industry leader in the region.

3D printing technology is just now becoming available, commercially. A color 3D printer creates a physical, three-dimensional gypsum-based model of any project from a digital prototype in nearly three million colors, allowing for exact detailing in every model.

"Our refined modeling process allows our clients to see and touch a new building at scale, but with its actual features. It enables our clients to make educated choices with less variance between their expectation and the actual outcome," states James B. Swiger, President of WYK Associates, Inc.

The decision to purchase a color 3D printer was not made lightly. Evaluating different brands, methods and technologies in 2013 and visiting maker labs and distributors in– and out-of-state, WYK opted for a solution tailored to the architectural environment and the company's clients, by choice the "greenest", most environmentally friendly model available to date.

To unleash the full potential of the 3D printer, WYK partners with ZDS Design/Consulting Services on 3D laser scanning. In the process of 3D laser scanning, laser beam signals that collect survey data points are used to capture images, make drawings and record measurements of a structure.

Combining the two technologies, existing buildings are scanned to the accuracy of one millimeter and then recreated as scale models on the 3D printer. An exciting combination - another first for the region – producing results greater than the sum of its parts.

"The possibilities are endless, and we have only just begun," says Swiger enthusiastically.


Shinnston Community Center Physical Model


Photo of Building Interior


3D Scan of Building Interior


3D Modeling of Robinson Grand Theater


3D Laser Scanning

Engineering for State & Local Government Facilities

Engineering planning and design for central heating plant, DDC controls, Air Handling Unit replacements and retrofits, operating and maintenance, training, heat recovery, fuel conversion, VFD's, variable water volume pumping, steam/heating hot water and chiller optimization.

Renovations included HVAC, fire safety, lighting, plumbing, indoor air quality and electrical power engineering.

LEED Certified Candidate

ZDS
Design/Consulting Services

Engineering for State & Local Government Facilities

ZDS engineering project experience includes facilities registered as official Historic Buildings

Jackie Withrow State Hospital

WEST VIRGINIA Department of Health & Human Resources

Hopemont State Hospital

WVDHHR hired ZDS to engineer the upgrades for three historic hospital facilities in three separate locations. ZDS successfully completed the projects while meeting the requirements of the State Historic Preservation Office (SHPO).

Mildred Mitchell-Bateman State Hospital

Renovations included HVAC, fire safety, energy efficient lighting, plumbing, indoor air quality and electrical power engineering.

ZDS
Design/Consulting Services

Engineering for State & Local Government Facilities

130th Airlift Wing at Yeager Airport,
Phase I and Phase II
Aircraft Maintenance Fuel Systems
Hangars and Shops
Awarded LEED Silver Certification

ZDS worked with the West Virginia Air National Guard on the Commissioning for their new Replacement Aircraft Maintenance Hangar and Shops plus a new Fuel Cell Hangar. This facility included a larger maintenance hangar, miscellaneous maintenance shops, central boiler plant and chiller plant. The project successfully achieved LEED Silver Certification with commissioning being an integral part of that certification.

Construction Costs:	**$43,000,000**
Project Size:	**128,715 ft^2**

"ZDS's commissioning services were invaluable in helping us understand our facility and ensure the systems were installed as intended and optimized for long-term operating benefits. We would recommend them again!" *- Captain Harry Netzer, WVANG Project Manager*

ZDS
Design/Consulting Services

William R. Sharpe, Jr. Hospital

Weston, WV

ZDS 25th Anniversary
DESIGN/CONSULTING SERVICES

WEST VIRGINIA Department of Health & Human Resources

Size: 219,754 ft^2 plus 33,000 ft^2 Addition

Date Complete: 2017

219,754 ft^2 Renovation plus 33,000 ft^2 New Construction

Prime for Engineering Master Planning, HVAC Renovations, Lighting Upgrades, Emergency Generator, Fire Protection, Electrical Renovations, Roof Replacement, Commissioning, 3D Scanning. Consultant for all MEP engineering through IKM, Inc. for the addition.

MEP Engineering design and Commissioning services for both the HVAC/lighting/roof Renovation project retrofitting Hospital and the patient wing addition. Comprehensive MEP engineering and commissioning services for a central domestic hot water services, central boiler/chiller plant and 1.8 MW bi-fuel emergency generator system. VWV Pumping for heating, cooling and domestic hot water. Integrated DDC controls for central monitoring, troubleshooting and control including demand control ventilation and outside air measuring/monitoring. The HVAC system is also an integral part of the smoke control system. Lighting systems upgraded to LED and controlled to minimize energy. IAQ enhancements were incorporated into the high performance HVAC systems. Careful phasing, and the need to disrupt only small portions of the Hospital at a time, resulted in an extended construction period.

"The ZDS staff are great planners and designers! They help us make the best decisions for the long term. We would recommend them to anyone!"
former Chief Operations Officer

Renovations resulted in a <u>48% reduction</u> in lighting and <u>28.8% reduction</u> in energy for HVAC renovations over ASHRAE 90.1-2001 standards qualifying the project for EPAct.

Construction Costs: Phase I HVAC Cost	$ 1,403,000	Completed in 2011
ARRA Funded Lighting Upgrade Costs	$ 618,700	Completed in 2011
Comprehensive Renovation Cost	$30,000,000	Completed in 2017
Addition Project Cost	$13,500,000	Completed in 2014

University of Charleston, Charleston, WV
Russell & Martha Wehrle Innovation Center

ZDS 25th Anniversary
DESIGN/CONSULTING SERVICES

Project Cost: $17,000,000, **Size:** 117,500 ft^2 **Date Complete:** 2017

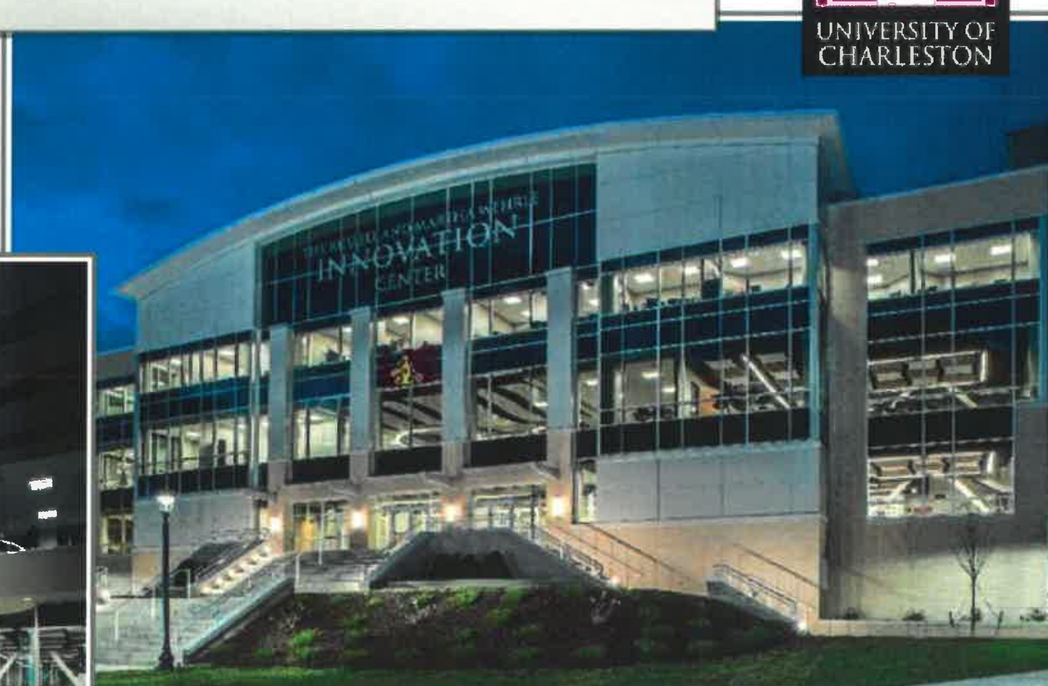
Study/Evaluation, HVAC Renovations, Lighting Upgrades, Fire Protection, Electrical Renovations, 3D Scanning

Client Reference: Gary Boyd, Director of Facilities; (304) 357-4871

The facility consists of classrooms, offices, flexible meeting areas and a large two-story Innovation Center space. Mechanical and Electrical work includes new chiller and boiler plants with pumps and accessories, HVAC air handling units, DDC Controls, new domestic and fire protection water services, new gas service, domestic water heating equipment, extensive plumbing fixtures/showers/lockers, new electrical service from the campus 12.5 kv distribution loop, switchgear, distribution and branch panel boards, and new state-of-the-art energy efficient LED lighting systems.

Renovations resulted in over a 50% reduction in energy over ASHRAE 90.1-2007 standards.

UNIVERSITY OF CHARLESTON



Project Experience

COMMISSIONING

ZDS 25th Anniversary
DESIGN/CONSULTING SERVICES

The Prince Jonah Kūhiō Kalaniana'ole (PJKK) Federal Building and United States Courthouse Honolulu, Hawaii

130th Airlift Wing at Yeager Airport, Phase I and Phase II: Aircraft Maintenance Fuel Systems Hangars and Shops

Awarded a **LEED Silver Certification** for each of the two phases

"ZDS's commissioning services were invaluable in helping us understand our facility and ensure the systems were installed as intended and optimized for long-term operating benefits. We would recommend them again!" - **WVANG Project Manager**

Harvard University Arnold Arboretum Weld Hill Research and Administration Building

LEED Gold Certified

- Kanawha County Schools
- General Motors (GM) of North America
- Maryland – Calvert County Indoor Aquatic Center
- Mercer County Schools
- Montgomery County Dept of Correction and Police
- Ohio University – Chillicothe Campus
- Raleigh County Schools
- Santa Ana Federal Building Renovations
- Pendleton County Middle-High School
- Tyler County Consolidated Middle-High School
- University of California, Davis School of Veterinary Medicine Instructional Facility
- Washington & Lee University
- WV Air National Guard
- WV Museum of Culture and Natural History
- WV State Capitol Complex
- West Virginia University Downtown Campus
- CAMC General, Memorial Division, Women & Children's Hospital
- United Hospital Center

PROJECT EXPERIENCE

Facility Dynamics
ENGINEERING

Montgomery County Judicial Center Annex

Rockville, MD

PROJECT DETAILS

SIZE
518,000 SF

DATE
2009-2018

CONSTRUCTION COST
$140.63M

PROJECT REFERENCE
Mr. Randy Hawkins
240.777.6099

PROJECT SPECIFICS

- Prime Cx Authority
- New Construction
- Phasing
- Security
- 6-Story Building
- Mechanical Penthouse
- County Judicial Center
- Public Use Spaces
- 14 New Courtrooms
- LEED Gold

PROJECT TEAM
Dave Stabler, PE

Facility Dynamics has built a trusted relationship with Montgomery County for 17 years spanning nearly 25 projects including the Public Safety Headquarters, the Regional Recreation and Aquatic Center, the Multi-Agency Service Park Extension, and the Equipment Maintenance Operations Center.

FDE is providing commissioning services to the 191,000 SF Annex addition and renovation of the existing 327,000 SF Judicial Center for Montgomery County (MD) government. The expansion will include 10 new courtrooms and administrative spaces. It will also house additional expansion space and Juvenile and Family divisions. It includes a green roof with plants and trees to absorb rainfall, solar panels, stormwater management system, and energy efficient mechanical systems.

FDE's scope for commissioning services covers all HVAC and HVAC controls systems including: central air handling unit systems with energy recovery, hydronic heating systems, VAV terminal units with hot water reheat, fan coil units, exhaust systems, humidifiers, new chillers and chilled water system. Other systems include: security systems, lighting controls, emergency power, fire alarm, generators, building automation system and plumbing systems which include: water heaters, domestic water booster systems and plumbing pumps.

EXPERIENCE

City of Seattle, Various Projects

Seattle, WA

PROJECT DETAILS

SIZE
Varies, 7 projects

COST
Varies

DATE
2018

PROJECT SPECIFICS

- LEED Platinum
- Energy Efficient Mechanical Systems
- Top Performing Building
- Fire Station 20 reduced energy usage by 70%

PROJECT REFERENCE
City of Seattle
Jeremy Nichols
206.684.0647
jeremy.nichols@seattle.gov

The City of Seattle contracted Facility Dynamics Engineering to be their third party control system design firm. This process resulted in the development of a number of city control system/ control network/control design documentation standards.

The third party process has enabled The City of Seattle to enhance the coordination of the MEP and Architectural design with the control system design. It has also enhanced the coordination of the equipment submittals to ensure that proper interface between the equipment and controls system by identifying potential conflicts between the equipment provided controls and the building controls systems prior to installation.

Facility Dynamics Engineering supported the commissioning process by monitoring the installation process and aiding with the coordination of installation details and integration to mechanical systems to ensure the proper sequence of operations is achieved. FDE coordinated with the design and construction team in the field to identify and agree on the specific location for each input and output device, especially in areas where Architectural issues will come into play. Additionally, FDE reviewed the commissioning plan and testing documents to ensure proper adherence to the design requirements. FDE performed controls trend and graphic reviews to ensure proper operation and adherence to the client standards.

Elevator Installations

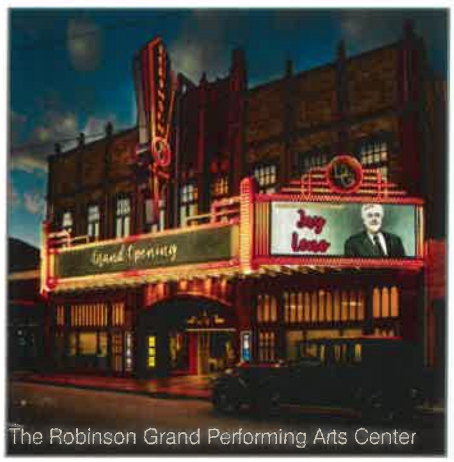
Throughout West Virginia

WYK ASSOCIATES, INC.
ARCHITECTURE•PLANNING

Pocahontas County Courthouse

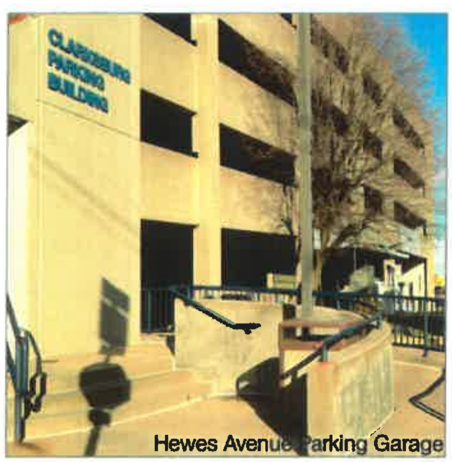
Glenville First Baptist Church

Koupal Towers



The Robinson Grand Performing Arts Center

Gore Hotel



Hewes Avenue Parking Garage

Elevator Renovation in Existing Building

- Hewes Avenue Parking Garage-1999
- Lewis County Middle School
- Robinson Grand Performing Arts Center
- Washington Irving Middle School
- Koupal Towers (Under Construction)

WYK Elevator Installations

New Exterior Tower Additions

- Bridgeport United Methodist Church
- First United Methodist Church - Clarksburg
- Preston County Courthouse
- VFW Post 573 - Clarksburg

New Construction

- Barbour County Bank
- Braxton County Courthouse
- Bridgeport High School
- Christie-Cutlip Office Building
- Dominion Exploration and Production
- First Baptist Church of Glenville
- Harrison County Bank - Bridgeport
- Harrison County Senior Center
- Hewes Avenue Parking Garage-1975
- New Bethel United Methodist Church
- Peterson Central Elementary School
- Morgantown Orthopedic Associates
- Taylor County Courthouse Annex
- Total Dental
- Robinson Grand Performing Arts Center
- West Union Bank -Newpointe
- Branch White Collar Crime Center
- WVANG Fixed Wing Training Center

New Elevator in Existing Building

- Gore Hotel
- Frank and Jane Gabor Folklife Center at Fairmont State University
- Pocahontas County Courthouse
- Barbour County Courthouse
- Clarksburg YWCA
- Harrison Clarksburg Health Dept.
- Harrison County Senior Center
- Annex
- Lumberport Middle School
- Medbrook Eye Clinic (Under Construction)

WYK ASSOCIATES, INC.
ARCHITECTURE•PLANNING

Frank & Jane Gabor WV Folklife Center

Fairmont State University, Fairmont, West Virginia

The Folklife Center - A Success Story

Living history carefully updated

Originally a barn, this historic building is at Fairmont State University's new main campus entrance. This charming stone building was previously used as apartments and storage.

It is now the home of Fairmont State University's West Virginia Folklife Program and also serves the school as a Visitor's Center.

By removing the third floor and gutting the second floor plan, WYK designed a two story day lit gallery space on the existing second floor. Remedial structural repairs were needed to brace the existing roof structure once the third floor was removed.

The first floor houses offices, classrooms and informal gathering spaces. An elevator, replacement of 72 windows and doors, natural and specialized lighting, sprinkler system and HVAC systems have all been integrated into this structure.

By marrying the historic character of the building with upscale contemporary features and educational elements, the Folklife Center welcomes alumni, students, faculty and the general public to share many public functions.

WYK ASSOCIATES, INC.
ARCHITECTURE • PLANNING

Robinson Grand Performing Arts Center
Restoration / Renovation
Clarksburg, West Virginia

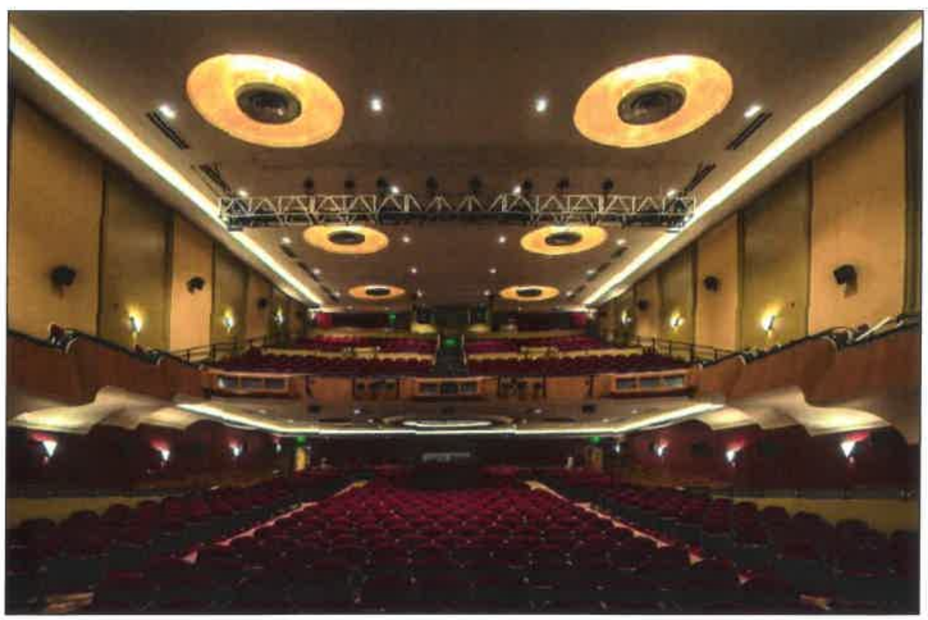
Historic property brought back to life!

Local theatre to revive downtown

The Robinson Grand Performing Arts Center is comprised of several different layers of classifications, including restoration, rehabilitation, renovations and additions. The 45,000 S.F. project included the restoring of the building's exterior masonry, updating the performance hall to seat over 1,000 guests, adding all new HVAC, finishes, electrical, sound, stage rigging, plumbing, complete roof replacement, concessions, restrooms, stage curtains, lighting, sound systems, dressing rooms, LED lighting, a barrel vaulted ballroom, a multi-purpose educational center, caterer's and preparation kitchens, circular bar, two new elevators, a loading dock and state-of-the-art marquee as well as structural enhancements throughout the building.

The City of Clarksburg purchased the building in April of 2014 and hired WYK in June of 2014 to begin the conceptual design process. WYK worked closely with the WV State Historic Preservation Office and the Owner's tax credit Consultants from the very beginning stages of design. A large portion of this project focused on conducting an ADA / building code assessment and designing the proper solutions. These included: ADA compliant restrooms, a new elevator, and the creation of new accessbile routes throughout the center, which has 15 different levels.

The project was ultimately awarded $6.5 million in state and federal historic and new market tax credits. Other awards the Robinson Grand recieved include the 2018 Excellence in Construction Award from the Associated Builders and Contractors, Inc. West Virginia Chapter.The project was completed in October of 2018.



Awards:

2018 Project of the Year by the Exponent Telegram
WV Municipal League All Star Community Award
WV Contractors Association Award (March-Westin)
(2) AIAWV Awards

2019 Community Affodable Housing Equity Corp (CAHEC) Outstanding Community Impact Award
2019 Historic Preservation Award for Downtown Preservation

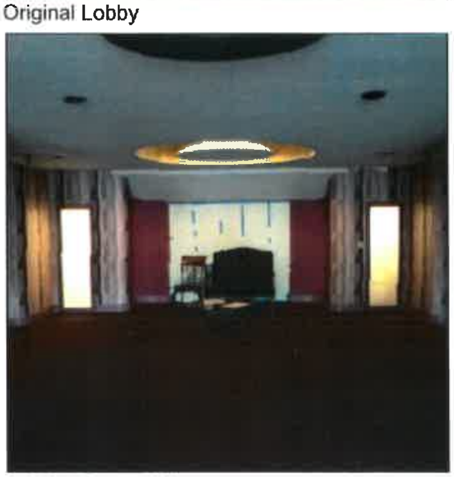
Robinson Grand Performing Arts Center
Restoration / Renovation

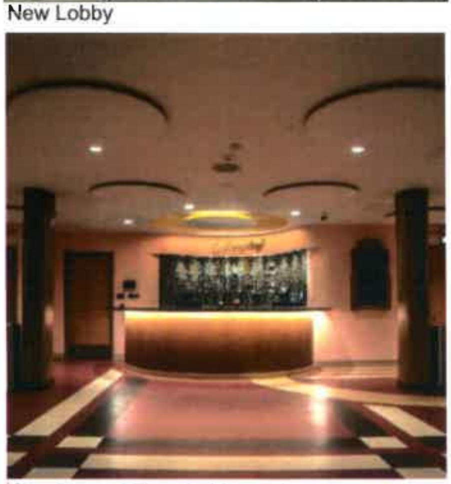
Clarksburg, West Virginia

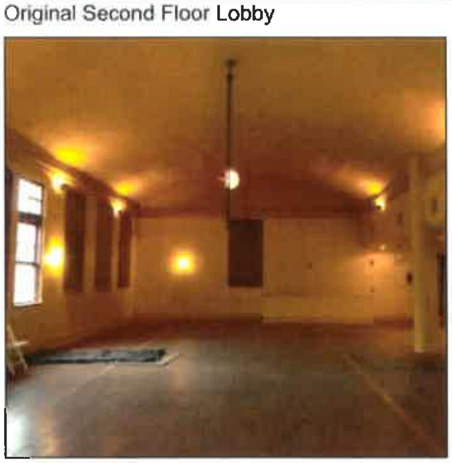
WYK ASSOCIATES, INC.
ARCHITECTURE•PLANNING

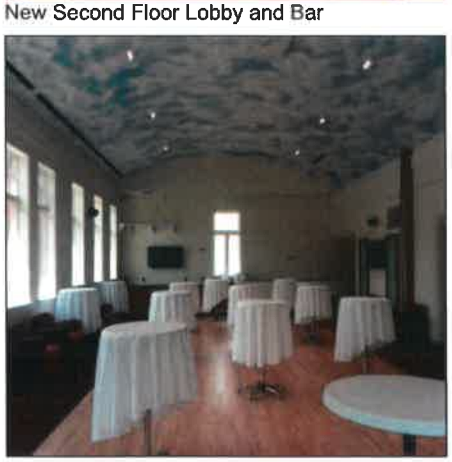

Original Lobby


New Lobby


Original Second Floor Lobby


New Second Floor Lobby and Bar


Original Ballroom


New Ballroom

Project Facts

- Original Bldg: 1913
- Theatre Fire: May 1939
- Rebuilt: December 1939
- Closed: 2000
- Bought by City: 2014
- Renovation Completed: 2018
- 45,000 Square Feet

Project Partners

- www.wykarchitects.com
- www.aurora-llc.com/
- www.studioilighting.com
- www.casstruceng.com
- www.wrldesign.com
- www.zdsdesign.com
- www.pcscmservices.com

Winner of Two AIA WV 2019 Design Awards

WYK ASSOCIATES, INC.
ARCHITECTURE • PLANNING

Gore Building Build-Out

Clarksburg, West Virginia

Historic building to provide upscale living in Clarksburg !

The Gore Hotel, located on West Pike and South Second Streets in downtown Clarksburg, served originally as a prestigist hotel in the 1920's It was built in 1913 by Truman E. Gore and Howard M. Gore, Governor of West Virginia and U.S. Secretary of Agriculture, respectively.

The 3rd, 4th, and 5th floors are being rehabilitated from multiple small hotel type rooms into seven seperate luxury apartments per floor with one and two bedroom options.

The inside of the exterior walls have been stripped of their orginal plaster and will be cleaned and sealed to leave a unique texture and feel to the apartments. The living areas will have laminate flooring while the bathrooms will have ceramic tile.

A new, large elevator and shaft is being installed to accomodate all levels of the building. Each floor will have a common area for residents to mix and socialize.

Project Facts
Size: 40,000 sq ft
Completed: Spring 2016
www.wykarchitects.com

Organization Chart / Proposed Team

State of WV Purchasing Division
Building Four Renovations Third Party Review

Ted Zachwieja III, PE, CEM
CTO/BIM Manager
MEP Engineer

ZDS
Management Team

Todd Zachwieja
PE, CEM, LEED AP
Principal-in-Charge

Jim Watters
ZDS MEP Design
Cost Estimating/CA

Chase Thomas, PE
ZDS MEP Engineer
Commissioning/Controls

James Swiger, AIA
WYK President/Architect

Jay Santos, PE
FDE Principal
MEP Engineer

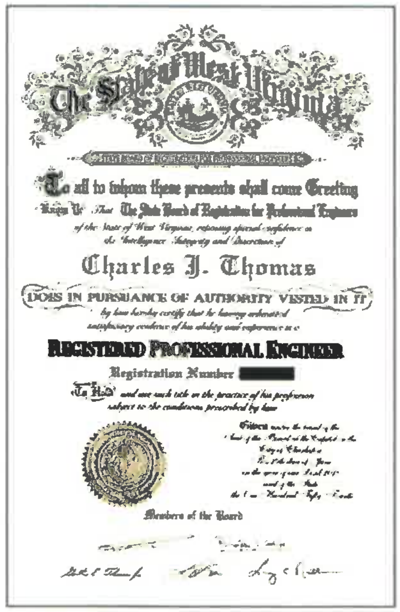
Tim Scruby, PE
FDE MEP Engineer

David Rush, PE
FDE MEP Engineer

Team Certifications

ZDS 25th Anniversary
DESIGN/CONSULTING SERVICES


The State of West Virginia
To all to whom these presents shall come Greeting
Know Ye That The State Board of Registration for Professional Engineers of the State of West Virginia, reposing special confidence in the Intelligence, Integrity and Discretion of
Ted A. Zachwieja
Does In Pursuance of Authority Vested In It by law hereby certify that he having submitted satisfactory evidence of his ability and experience, is a
Registered Professional Engineer
Registration Number [redacted]
To Hold and use such title in the practice of his profession, subject to the conditions prescribed by law.
Given under the hand and the Seal of the Board, at the Capitol in the City of Charleston, this twentieth day of Feb in the year of our Lord One Thousand Nine Hundred and eighty seven and of the State the One Hundred twenty third.


The State of West Virginia
To all to whom these presents shall come Greeting
Know Ye That The State Board of Registration for Professional Engineers of the State of West Virginia, reposing special confidence in the Intelligence, Integrity and Discretion of
Charles J. Thomas
DOES IN PURSUANCE OF AUTHORITY VESTED IN IT by law hereby certify that he having submitted satisfactory evidence of his ability and experience is a
REGISTERED PROFESSIONAL ENGINEER
Registration Number [redacted]
To Hold and use such title in the practice of his profession subject to the conditions prescribed by law
Members of the Board


The State of West Virginia
To all to whom these presents shall come Greeting
Know Ye That The State Board of Registration for Professional Engineers of the State of West Virginia, reposing special confidence in the Intelligence, Integrity and Discretion of
Ted Anthony Zachwieja III
DOES IN PURSUANCE OF AUTHORITY VESTED IN IT by law hereby certify that he having submitted satisfactory evidence of his ability and experience is a
REGISTERED PROFESSIONAL ENGINEER
Registration Number [redacted]
To Hold and use such title in the practice of his profession subject to the conditions prescribed by law
Members of the Board

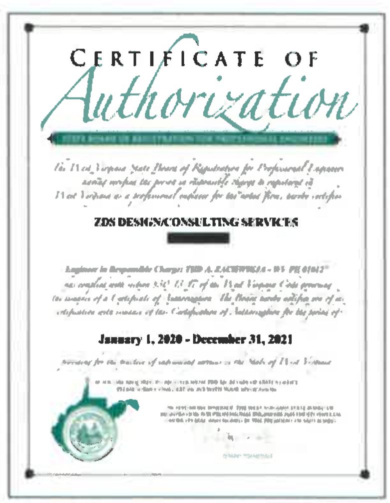

U.S. Green Building Council
Ted A. Zachwieja
LEED ACCREDITED PROFESSIONAL


aee CEM
The Association of Energy Engineers
certifies that
Ted A. Zachwieja
CERTIFIED ENERGY MANAGER®
[redacted]
ANSI


aee CEM
The Association of Energy Engineers
certifies that
Ted A. Zachwieja III
CERTIFIED ENERGY MANAGER®
[redacted]
ANSI


National Fire Protection Association
Be it known that NFPA recognizes
JAMES WATTERS
as a Member in Good Standing and is entitled to all the rights, honors and privileges of membership


State of West Virginia
Certificate
I, Natalie E. Tennant, Secretary of State of the State of West Virginia, hereby certify that
ZDS LIMITED LIABILITY COMPANY
CERTIFICATE OF EXISTENCE
Given under my hand and the Great Seal of the State of West Virginia on this day of December 03, 2015


CERTIFICATE OF Authorization
STATE BOARD OF REGISTRATION FOR PROFESSIONAL ENGINEERS
ZDS DESIGN/CONSULTING SERVICES
[redacted]
January 1, 2020 - December 31, 2021

Todd Zachwieja, PE, CEM, LEED AP

ZDS Design/ Consulting Services

Todd has over 40 years of experience involving the analysis, design, construction management and specifications for mechanical engineering, heating, ventilating, air conditioning, plumbing, fire protection, electrical and lighting, as well as indoor environmental quality analysis, building system commissioning and forensic engineering for educational, governmental, military, commercial, industrial and health care clients. He is also recognized as a campus master planner for utility infrastructure providing master planning at many Universities, hospitals and the State of WV Capitol Complex.

Prior to starting a consulting engineering firm, Todd Zachwieja coordinated comprehensive energy conservation programs resulting in annual energy savings of millions of dollars. He has managed a profitable regional office for one of the country's largest energy companies that service the southeastern United States. Todd also developed computer modeling programs for building energy analysis and monitoring. He has been invited as an industry leader to present technical papers and speak at professional conferences both regionally and nationally.

Todd selected and designed the pilot project for one of the largest geothermal heat pump applications in the Eastern US including designing custom geothermal rooftop AHU's. He has retro-commissioned HVAC systems for millions of square-feet for facilities located in 10 states. He has been involved with many commercial structures including high-rise commercial building renovations. Todd designed renovations to many existing schools which received ***Energy Star Certifications*** placing them in the nation's top 25% of energy efficiency schools. *The College Planning and Management Magazine* featured Todd and his work with a major University for the performance contracting programs that save millions of dollars in energy and operating costs. Most projects also qualified for EPAct which requires buildings use over 50% less energy than buildings designed using ASHRAE 90.1.

GOVERNMENT/HISTORIC/COMMERCIAL PROJECT EXPERIENCE

- Bank One
- Bayer Material Science
- Calvert County Aquatic Center, MD
- Charleston Area Medical Center
- Cass Scenic Railroad Clubhouse, WVDNR
- Coal Heritage Discovery Center
- Culture Center, HVAC & Fire Protection, WV State Capitol Complex
- General Motors Corp. Re-commissioning
- Hopemont Hospital, WVDHHR
- Jackie Withrow Hospital, WVDHHR
- Jackson County Courthouse Annex
- Kanawha County Commission: 120,000 sf Judicial Annex additions/renovations
- Kanawha County Courthouse
- Kanawha County Metro 911
- Kanawha County Public Library
- Kanawha County Schools
- Kohl's
- Laidley Towers
- Marshall University
- Mercer County Courthouse Annex
- Olin Corporation
- Phillip Morris USA
- Public Service Commission of WV
- Redmond House, WVDOT
- Rhone-Poulenc
- Robinson Grand Performing Arts Theatre
- Santa Anna Federal Building, CA
- St. Patrick's Church
- Tyler County Courthouse
- Tyler County Schools
- Toyota Motor Manufacturer, WV Inc.
- Union Carbide/DOW
- United Center
- University of Charleston Innovation Ctr
- William R. Sharpe, Jr. Hospital, WVDHHR
- Word Trade Center, MD
- WV Air National Guard including Cx $45M Fuel Cell/ Maintenance Hangars at Yeager Airport – ***LEED Silver Certified***
- WV Army National Guard
- WV Capitol Complex Central Heating Plant
- WV Children's Home, WVDHHR
- WV Department of Transportation/DOH
- WV Division of Protective Services
- WV Higher Education Authority
- WV General Services Division
- WV State Capitol Complex renovations
- WVU Stewart Hall & Wise Library
- Yeager Airport

PROFESSIONAL REGISTRATIONS

Professional Engineer:

Florida [redacted]
Georgia [redacted]
Kentucky [redacted]
Maryland [redacted]
North Carolina [redacted]
Ohio [redacted]
Pennsylvania [redacted]
South Carolina [redacted]
Virginia [redacted]
West Virginia [redacted]

Fire Investigation Certification under the direction of Peter Vallas, Sr.

CEM

Certified Energy Manager (C.E.M.) National Certification No. [redacted]

LEED AP

LEED Accredited Professional, National Certification through USGBC No. [redacted]

EDUCATION

Masters of Science in Engineering Management from West Virginia University College of Graduate Studies.

Bachelor of Science in Mechanical Engineering from West Virginia Institute of Technology.

Todd Zachwieja, PE, CEM, LEED AP

PROFESSIONAL AND COMMUNITY AFFILIATIONS

Member of Investigative Engineers Association (I-ENG-A) and founder of I-ENG-A of the Tri-State Region

Past President 2013-14, current Governor - WV ASHRAE Chapter, Served as ASHRAE's Energy and Technical Affairs Chairman for six years. Recognized by ASHRAE Region VII in 2014 with the David Levine Award of Excellence, Presidential Award of Excellence,

Recognized by the International Who's Who of Professionals

Recognized nationally as West Virginia's Business Man of the Year

Recognized by AEE nationally in 2007 as a Legend in Energy

Recognized by AEE nationally in 2008 as a Charter Legend in Energy

Charter Life Member of the Association of Energy Engineers

Professional Affiliate Member of the American Institute of Architecture

Associate Member West Virginia Society for Healthcare Engineering

Member of the International Code Council

Member of the National Society of Professional Engineers

OTHER RECOGNITIONS

Selected by WVU and the WV Division of Energy to train Code officials and the design community on ASHRAE 90.1 State Energy Code

Presented at regional and national conferences including the annual National System Commissioning Conference

Contributing editor and served on the Editorial Review Panel for *"The Handbook of Building Management and Indoor Air Quality"*

Contributing editor *"Ventilation for a Quality Dining Experience"*

Contributing editor and served on the Editorial Review Panel for *INvironment Professional, Power Prescriptions* and other publications and articles featuring Indoor Air Quality (IAQ) and MEP engineering systems

Energy Star Certified for facilities in the nation's top 25% of energy efficiency

1st Place 2014 ASHRAE Technology Award, Region VII

LEED Silver Certified WVANG Fuel Cell/Maintenance Hangar, Charleston, WV

LEED Gold Certified Harvard Arboretum, Boston, MA

First ASHRAE bEQ certified building in West Virginia, 2015

Ted Zachwieja III, PE, CEM

Ted has over 16 years of experience in building construction design industry. His strategic thinking and development of technical resources at ZDS has helped streamline design processes and improve quality of work office wide. Ted is an innovative problem solver in engineering design, communication methods and management of BIM models between stakeholders during a design project. As a pioneer and a believer in technological processes Ted has championed Integrated Design Practices that has become the fabric of ZDS's day to day operations.

Ted developed ZDS's 3D Scanning services which have assisted in collecting key existing conditions for renovation projects, forensic engineering, historical preservation, and high definition reality capture. Ted has in depth experience on collection, registration, and scan to BIM processes. He has provided training and developed materials for best practices when using 3D scan data. Ted's 3D scanning experience includes governmental, educational, health care, industrial, and commercial facilities. He also has experience in speaking on how 3D laser scanning impacts our industry today.

Ted develops, designs and manages the IT systems. The experience encompasses development and deployment of central server systems to networked client computer systems, strategic development for ZDS' Integrated Design Processes, and research and development into new technologies to continue staying on the cutting edge for ZDS and others.

Ted's project experience includes design and commissioning for heating, ventilating, air conditioning, plumbing, fire protection, electrical and lighting systems for educational, health care, industrial and commercial facilities. His experience encompasses working both on new construction and renovation projects. He also is experienced in historical facilities including theatrical.

Ted maintains an active membership to the ASHRAE professional society and also has a lifetime membership to the Association of Energy Engineers. He maintains an active continuing education towards today's standards and codes as well as participates in ASHRAE at both a local and society level. He was recently appointed to the Electronic Communications Standing Committee with ASHRAE. Ted has designed renovations to existing K-12 schools which received ***Energy Star Certifications*** placing them in the nation's top 25% of energy efficiency schools.

GOVERNMENT/HISTORIC/COMMERCIAL PROJECT EXPERIENCE

- WV Air National Guard Maintenance Hangar and Fuel Cell Hangar, Charleston, WV – ***LEED Silver Certified***
- Adams Morgan Historic Hotel, DC
- Bayer Material Science
- Catholic Church of Ascension, Parish Hall Renovations
- Coal Heritage Discovery Center
- Culture Center, WV State Capitol Complex
- Highland Museum, KY
- Hopemont Hospital, WVDHHR
- Jackie Withrow Hospital, WVDHHR
- Kanawha County Judicial Annex HVAC Renovations
- Laidley Towers
- Meadowbrook Rest Areas
- I-70 Welcome Center
- CASCI Building, Charleston WV
- Morgantown Welcome Center
- Pocahontas County Community Center
- Redmond House, WVDOT
- Robinson Grand Performing Arts Theatre
- Servia Rest Areas
- St. Patrick's Church, Weston WV
- Stonewall Jackson Marina
- Tyler County Courthouse
- University of Charleston Innovation Center Additions/Renovations
- William R. Sharpe, Jr. Hospital Additions/ Renovations, WVDHHR
- World Trade Center, Renovations, MD
- WV Children's Home, WVDHHR
- WV Parkways Authority, Toll Booth Plazas
- WV State Capital Complex Central Heating Plant
- WVU Wise Library
- White Sulfur Springs Rest Area
- Numerous K-12 School Renovations

PROFESSIONAL REGISTRATIONS

Professional Engineer:

Florida [redacted]

West Virginia [redacted]

Certified Energy Manager (C.E.M.)

National Certificate

No. [redacted]

EDUCATION

Bachelor of Science in Mechanical Engineering from Rochester Institute of Technology, Rochester, NY

AWARDS AND RECOGNITIONS

Awarded 2012 Legend in Energy by the Association of Energy Engineers

Awarded acceptance into ASHRAE's 2015 Leadership University

ASHRAE Blue Ribbon Award of Excellence

Co-Author at Autodesk University

Energy Star Certified for facilities in the Nation's top 25% of energy efficiency

Member & Co-Founder I-ENG-A of the Tri-State Region

Jim Watters

ZDS 25th Anniversary
Design/ Consulting Services

Jim has over 40 years' experience in design and implementation of lighting, HVAC, plumbing and electrical systems including nine years in the construction industry. He has a comprehensive knowledge of construction documents, contracts, and development of cost estimates, budgets and schedules. Jim's strengths reside in his ability to manage projects and people in an organized and cost-effective manner. Jim has been involved with the design and production of mechanical and electrical drawings including HVAC, plumbing, fire protection, lighting, electrical power, fire alarm and specialized systems. He has worked with and managed engineers in projects for health care, educational and commercial buildings in the states of West Virginia, Florida, Maryland, Pennsylvania, Ohio, Kentucky, Virginia, Georgia, New York, Arizona, Illinois and Massachusetts.

Jim has extensive experience in energy savings' programs for lighting, HVAC, plumbing and electrical systems in hospitals, state and government office buildings, school systems, and manufacturing facilities, as well as managing performance contracts for a large facility's campus totaling $10,000,000 in construction costs on various projects, including the conception, design and construction administration for the installation of a 1.5 Megawatt emergency generator. The propane-fired generator and associated switchgear in conjunction with 60,000 gallons of propane fuel storage served to provide peak shaving/load shedding to save on the campus utility costs as well as emergency power functions. Through the years, Jim has researched and implemented into practice International Building Codes, NFPA Codes, National Electrical Codes, Life Safety Codes, IES standards, AIA Guidelines for Design and Construction, and ADA guidelines. His involvement in construction through the years has been mainly from the design side of the industry with a 9 year stint working for a contracting firm at the turn of this century. His experience includes coordinating with Architects, Owners and Agencies including an excellent relationship with the office of State Fire Marshal.

GOVERNMENT/HISTORIC/COMMERCIAL PROJECT EXPERIENCE

- Bluefield Area Transit Authority Administration and Maintenance Facility
- Kentucky Judicial Center, Boyd County
- Coal Heritage Highway Authority
- Chase Towers (formally Charleston National Bank)
- Culture Center Fire Alarm/Sprinklers, WV State Capitol Complex
- Department of Transportation Rest Area prototype
- Department of Transportation Welcome Center prototype
- Fenway Park Lightning Protection/ Grounding Study, Boston
- Glenville State College
- Hopemont Hospital, WVDHHR
- I-70 Welcome Center
- Jackie Withrow Hospital, WVDHHR
- Jackson County Libraries Renovations
- Kanawha County Commission Judicial Annex Renovations
- Laidley Towers
- Meadowbrook Rest Areas
- Morgantown Welcome Center
- Redmond House, WVDOT
- Rhone-Poulenc New Admin. offices
- Robinson Grand Performing Arts Theatre
- Sacred Heart Pavilion and Daycare Ctr
- St. Patrick's Church
- Shawnee Park Clubhouse
- Stonewall Jackson Marina Renovations
- Tucker County Board Office Boiler Retrofit
- Tucker County Courthouse
- Tyler County Courthouse
- University of Charleston Innovation Ctr
- William R. Sharpe, Jr. Hospital, WVDHHR
- World Trade Center, MD
- WV Air National Guard including Cx $45M Fuel Cell/ Maintenance Hangars at Yeager Airport – ***LEED Silver Certified***
- WV Children's Home, WVDHHR
- WV Department of Military Affairs, Public Safety Maintenance Facility, Eleanor
- WV Department of Transportation Burnsville Rest Area and Domestic Water Pumping Station—***AIA Merit Award Recipient***
- WV State Capitol Complex Renovations to Buildings 1, 3, 4, 5 & 7
- White Sulphur Springs Welcome Center

PROFESSIONAL AFFILIATIONS

Member of Investigative Engineers Association (I-ENG-A) of the Tri-State Region

Member of the National Fire Protection Association (NFPA)

Member of the Health Care Section of the NFPA

Member of the Illuminating Engineering Society (IES)

Past member of the American Society of Plumbing Engineers (ASPE)

Past member of the Institute of Electrical Engineers (IEE)

OTHER RECOGNITIONS

Energy Star Certified for facilities in the Nation's top 25% of energy efficiency

Chase Thomas, PE

ZDS 25th Anniversary
Design/ Consulting Services

Chase has over 10 years of experience providing design, Construction Administration and Commissioning services in mechanical, plumbing, fire protection and various electrical systems. His experience encompasses a broad range of Projects including, but not limited to, Commercial, Government, Healthcare, Educational and Industrial facilities. These Projects over the years have ranged extensively from small to large in terms of both physical sizes and construction budgets. He also has construction experience adding a practical hands on knowledge to both design and commissioning.

Chase's specializes in the design/commissioning and layout of HVAC systems, fire protection/ sprinkler systems, lighting and other electrical systems. He has an excellent understanding of the design and implementation of piping systems encompassing all domestic water, sanitary waste/vent, storm water and natural gas combined with a knowledge in steam/water heating systems, boilers, pumps, recirculating systems, Thermostatic Mixing Valves, etc. He consistently stays current with applicable Codes and national, as well as local, standards and regulations.

He has a good awareness of all aspects of the design process and how the various disciplines need to be coordinated to avoid conflicts during construction. Chase has maintained growth as technology has changed throughout the years in the field of engineering design and drafting standards beginning with varying degrees of CAD drafting and proficient in BIM/REVIT and energy modeling.

Chase is the President for the WV ASHRAE professional society . He maintains an active continuing education towards today's standards and codes as well as participates in ASHRAE at both a local and society level. He has also continued his education with relevant courses associated with the field of engineering, and has been active in leadership training provided through ASHRAE and other highly reputable coaching services.

PROJECT EXPERIENCE

- Ashland Community & Technical College HVAC Controls
- Ben Franklin Career Center HVAC Renovations and Commissioning; Kanawha County Schools
- NEW Bluefield Primary School Commissioning; Mercer Co. Schools
- Bluestone Dam Gate Controllers Electrical Renovations
- Bluestone & Dunbar Armory HVAC Renovations
- Bonsak Elementary (VA) HVAC Controls Renovations
- Cabell Huntington Hospital Surgery Center HVAC Controls Renovations
- CAMC Memorial Hospital Patient Rooms HVAC Renovations
- NEW Mountain Valley Elementary Commissioning; Mercer County Schools
- St. Mary's Hospital Patient Rooms HVAC Renovations
- North Central Regional Jail Renovations
- North Fork Elementary Renovations and Commissioning
- Pendleton County Middle/High School Renovations and Commissioning
- Tucker County High School HVAC Renovations
- Tyler County Courthouse
- Tyler Consolidate Middle/High School HVAC Renovations and Commissioning
- Urlings General Store Renovations
- West Edge Factory Renovations
- Weston Hampton Inn HVAC Retrofit
- WV Capitol Complex Central Heating Plant Renovations
- World Trade Center Renovations, MD

PROFESSIONAL REGISTRATIONS

Professional Engineer:
West Virginia [redacted]

EDUCATION

West Virginia University
Bachelor of Science
in Mechanical Engineering

AWARDS AND RECOGNITIONS

Member of Boy Scouts of America (Eagle Scout)

General Contractor License Holder

PROFESSIONAL AFFILIATIONS

President of WV ASHRAE

ASHRAE West Virginia Chapter

Member I-ENG-A of the Tri-State Region

ENERGY STAR

I-ENG-A of the Tri-State Region

RESUMES

Jay Santos, PE

PRINCIPAL

EDUCATION

University of Florida
Master of Science
Bachelor of Science
Mechanical I Engineering

REGISTRATIONS

Professional Engineer, MD, OH

Jay has more than 36 years experience in controls design, controls master planning, commissioning and training. A recognized expert with a preeminent record of conceiving and implementing innovative, energy and cost-efficient designs in the felds of DDC Controls, Building Controls Master Planning, and Building Automaton Systems (BAS), Jay is also a renowned lecturer, educator, and author.

Jay's specialties include originating and developing detailed Building Control Master Planning utilizing standardized approaches to sequences, documentation, and specifications; originating controls designs utilizing his expertise in controls analysis, trouble-shooting, and energy concerns; quantifying existing building control systems and offering recommendations detailing cost, energy savings, and operational impact; developing BAS User Guides covering interoperability concerns, architecture, hardware and software issues, and assisting owners and engineers in designing and selecting systems to best meet their BAS needs.

As Principal, Jay oversees review processes and identifies commissioning, retro-commissioning, and energy-conservation strategies based on his in-depth knowledge of the commissioning process and building optimization, supervises numerous commissioning projects, manages the implementation of PACRAT™(fault detection & diagnostic software) and provides technical support, and oversees contract administration and project quality control/ quality assurance. Jay teaches commissioning and DDC controls classes and conducts on-site training programs, provides technical training and consulting, and presents speeches and papers on commissioning, controls, and HVAC diagnostics.

RELEVANT EXPERIENCE

Anne Arundel County Public Schools, Annapolis, MD
Principal for the commissioning of 12 different replacement K-12 schools in the County including Lothian Elementary School and Annapolis High School.

Baltimore County Public Schools, Baltimore, MD
Principal for the commissioning of seven different replacement K-12 schools in the County including Victory Villa Elementary School, Lutherville Elementary School and Lansdowne Elementary School.

Howard County Public Schools, Columbia, MD
Anne Arundel Schools, Annapolis, MD
Principal for the commissioning of four different replacement K-12 schools in the County including Glenwood Middle School, Deep Run Elementary School and Mount Hebron High School.

RESUMES

Tim Scruby, PE

MECHANICAL ENGINEER

Facility Dynamics
ENGINEERING

EDUCATION

Virginia Polytechnic Institute and State University
Bachelor of Science
Mechanical Engineering

REGISTRATIONS

Professional Engineer, VA

LEED Accredited Professional

Tim Scruby is a Project Manager and Senior Controls Engineer with over 36 years of experience. Tim has an exceptional ability to analyze complex situations and develop innovative and successful solutions. As a Senior Engineer, Tim is responsible for planning, conducting, and overseeing numerous commissioning and re-commissioning projects including LEED-certified buildings, hospitals, museums, laboratory buildings, data and research centers. Tim has extensive knowledge in museum commissioning and archival storage requiring reduced humidity.

Additionally, Tim evaluates chilled water systems and assesses load analysis, then develops and implements cost-effective chilled water system designs; originates and implements remedial HVAC designs; executes controls commissioning; conceives, develops, and implements mechanical system master planning; conducts energy analysis and economic feasibility studies and offers recommendations; performs HVAC replacement studies; authors DDC articles for the Iowa Energy Center website; instructor of Advanced HVAC Commissioning courses; provides technical assistance and expertise.

RELEVANT EXPERIENCE

Albemarle County Public Schools, Crozet, VA
Tim retro-commissioned the Western Albemarle High School Environmental Studies Academy (ESA) providing reporting on induction terminal unit review for the school's new structure for its desired and needed natural sciences program.

Brownsville Elementary School, Crozet, VA
Tim provided commissioning services to the 32,000SF addition and renovations project that increased the existing school's capacity by nearly 200 students and gave students and teachers 10 new classrooms, a new gym and a much needed cafeteria expansion. Brownsville Elementary School was the first LEED Certifed school in Albemarle County with a reduction of 37% less energy than other schools its size.

Confidential Client, Multiple Locations
Tim has provided a variety of commissioning services for data centers nationally and internationally including all commissioning phases

University of Virginia Foundation, Charlottesville, VA
Tim led the commissioning efforts with the University of Virginia Foundation for the Battle Building at UVA Children's Hospital.

RESUMES

David Rush PE
MECHANICAL ENGINEER

EDUCATION
University of Maryland, College Park
Masters of Science
Systems Engineering

University of Maryland, College Park
Bachelor of Science
Computer Science

Lehigh University
Bachelor of Science
Mechanical Engineering

REGISTRATIONS
Professional Engineer, MD

Since 2005, David Rush has served as a Project Manager / Senior Mechanical Engineer with the Facility Dynamics Engineering team on multiple projects throughout the Baltimore/Washington corridor. His focus has been on educational institutions extending from K-12, higher education facilities including science buildings, cancer research, and laboratories.

He brings his 27 years of experience in Facilities Management/Engineering and Controls Engineering to every project along with a dedicated attention to detail and fiscal project approach. As a former steward of public monies in his role as a Senior Mechanical Engineer for the UMCP Department of Facilities Management, he values where dollars are spent on projects and understands the importance of doing every task with purpose and intent.

David has performed Analysis and Remedial Engineering of building HVAC and control systems for clients to determine if the systems are operating properly and complying with industry standards & local/national codes. He also assists colleagues with drawings, shop drawing review, field surveys and field testing as needed.

RELEVANT EXPERIENCE

Mercer County Schools, Green Valley, WV
David, with ZDS Design, has led the Cx specification development and the Final Cx Plan for Bluefield Elementary School and Mountain Valley Elementary School.

Tyler Consolidated Middle/ High School, Sistersville, WV
David, with ZDS Design, has started the commissioning process for this Tyler County school with the development of CACEA, the Controls and Commissioning Engineering Application that FDE utilizes to execute Cx projects.

Ben Franklin Career and Technical Center, Dunbar, WV
With ZDS Design, David completed functional performance testing and finalized design PFCs for this adult educational center for high school students and adults.

Anne Arundel County Public Schools, Annapolis, MD
David has led the commissioning of 12 different replacement K-12 schools in the County including Lothian Elementary School and Annapolis High School.

Baltimore County Public Schools, Baltimore, MD
David has led the commissioning of seven different replacement K-12 schools in the County including Victory Villa Elementary School, Lutherville Elementary School and Lansdowne Elementary School.

WYK ASSOCIATES, INC.
ARCHITECTURE•PLANNING

Team Profiles

James Swiger

www.wykarchitects.com > About WYK > Team

James B. Swiger AIA, NCARB, LEED AP BD+C

President/Principal-In-Charge

WYK Associates, Inc.
205 Washington Avenue
Clarksburg, WV 26301

304-624-6326

304-677-3373 Cell

304-623-9858 Fax

www.wykarchitects.com

james@wykarchitects.com

Memberships

WV AIA Board of Directors
2007 - 2009

He is a Harrison County native involved with several community and professional organizations.

James has gained broad experience in both the private and public sectors of the construction / design industry. His completed work reflects a variety of projects with values ranging from thousands of dollars to over $22 million.

EDUCATION

5-Year Bachelor of Architecture, 1996
University of Tennessee, Knoxville, TN
NAAB Accredited University

ARCHITECTURAL REGISTRATION

West Virginia (#3640)
Ohio (#1315976)
Pennsylvania (#RA-406309)
Virginia (#401016552)
Maryland (#0017689)
National Council of Architects (#58982)

HONORS AND AWARDS

2019 "Sharp Shooter" WV Executive Magazine

2019 AIA-WV Honor Award for Excellence in Architecture - Historic Preservation / AIA-WV Craftsmanship Award for Excellence in Architectural Detail and Craftsmanship; Robinson Grand PAC, Clarksburg, WV

2015 Clarksburg Uptown Business Member of the Year

2015 Campaign Chair - United Way of Harrison County, Inc.

2015 Harrison County Chamber of Commerce Education Committee Chair

2015 "Young Gun" WV Executive Magazine

2013 AIA-WV Merit Award for Achievement in Architecture Design - Unbuilt: Shinnston Community Center, Shinnston, WV

2013 AIA-WV Merit Award for Achievement in Architecture Design; Fairmont State University- Frank and Jane Gabor Folklife Center, Fairmont, WV - Interior and Exterior

Energy Star Certification, Elkins Middle School, Elkins, WV

2010-11 Cambridge Who's Who Member

2009 West Virginia Kiwanis District Governor's Award for "Promoting Membership Growth"

2008 Volunteer of the Year - Harrison County Chamber of Commerce

2008 Selected "Generation Next: 40 Under 40" by the West Virginia State Journal

2008 Strathmore's Who's Who Worldwide Recipient

2008 AIA-WV Merit Award for Achievement in Architecture; West Pike Street Parking Facility, Clarksburg, WV (Co-Design Architect)

PROFESSIONAL AFFILIATIONS

American Institute of Architects

AIA - West Virginia

National Council of Architectural Registration Boards

Accredited Professional
U.S. Green Building Council
Building Design + Construction

USGBC-WV Chapter

League of Historic American Theatres

National Trust for Historic Preservation

NFPA – National Fire Protection Agency

WVSHE – Associate Member of West Virginia Society for Healthcare Engineering

Affiliate Member of Builders Supply Association of West Virginia

CIVIC AFFILIATIONS

Health Access, Inc. - Board of Directors

Bi-County Nutrition, Inc. - Board Member

Clarksburg Uptown - President / Board of Directors

Bi-County Nutrition, Inc. - Board Member

Salem University - Advisory Committee to the School of Business

Central WV Corvette Club Member

Harrison County Chamber of Commerce – Board of Directors (2013-15)

United Way of Harrison County, Inc.; Board of Directors (2009-2016) - Executive Committee "Stonewall Leadership Contributor"; 2015 Campaign Chair

Kiwanis Club of Clarksburg 2008/2009 President

Kiwanis Division 3
2009/2010 Lieutenant Governor

Kiwanis Club of Clarksburg 2018 - Present Volunteer and Service Committee Chair

Salem Area Chamber of Commerce - Past Board Member

West Virginia Kiwanis District – District 3 – Past Lieutenant Governor

Harrison County Chamber of Commerce – Past Education Committee Chair

Salem Elementary School Nature/Fitness Trail – Project Manager

ZDS 25th Anniversary
DESIGN/CONSULTING SERVICES

References

ZDS has worked on hundreds of projects in West Virginia including many with Governmental agencies. We encourage you to call the references listed below:

1. **Greg Nicholson,** Retired Chief Operations Officer, WV DHHR: (304) 552-010; many projects with WVDHHR as well as William R. Sharpe Jr. Hospital additions, renovations and commissioning.

2. **Ron Adkins,** Construction Manager, WV Air National Guard & WVDHHR: (304) 957-0205, or (304) 634-9379; former Project Manager for WVANG and current Construction Mgr. for many projects with WV DHHR as well as William R. Sharpe Jr. Hospital additions, renovations and commissioning.

3. **Gary Boyd,** Director of Facility Services, University of Charleston & WVU: (304) 357-4871, garyboyd@ucwv.edu; worked on projects at both WVU and University of Charleston involving MEP systems since 1990's.

4. **Chuck Smith,** Executive Director of Facilities Operation, Kanawha County Schools & Kanawha County Commission: (304) 348-6148, dcsmith@mail.kana.k12.wv.us; for projects with Kanawha County Schools as well as previous projects with the Kanawha County Commission.

5. **Amanda Kimble,** Director of Facilities, Tyler County Schools: (304) 758-2145, akimble@k12.wv.us; for renovations to Tyler Consolidated Middle/High School.

WYK ASSOCIATES, INC.
ARCHITECTURE•PLANNING

1. **Geoff Marshall,** CHFM, CHC, Vice-President of Support Services, United Hospital Center, Bridgeport, WV: (681) 342-1220.

2. **Ryan Tolley,** Executive Director, Robinson Grand Performing Arts Center: (304) 624-1500 ext. 6; trolley@therobinsongrand.com.

3. **Steve Haning,** Diamond Development LLC: (304) 622-1562.

Facility Dynamics
ENGINEERING

1. **Richard Morse,** Capitol Projects Manager, The County of Henrico Virginia: (804) 501-7227, mor33@co.henrico.va; Building Commissioning Services, Controls Engineering, Engineering Consulting.

2. **Jim Taylor,** Virginia Department of Behavioral Health & Developmental Services: (804) 840-71558; jim.taylor@dbhds.virginia.gov; Building Commissioning Services, and other Engineering Services.

Tyler County Schools

P.O. Box 25
Middlebourne, WV 26149
(304) 758-2145
Fax (304) 758-4566

A. Shane Highley, Superintendent

Linda Hoover, President
Katrina Byers, Vice-President
Dave Roberts, Member
Larry Thomas, Member
P.J. Wells, Member

February 4, 2020

To Whom It May Concern:

This letter is to recognize the outstanding performance of ZDS Design/Consulting Services regarding their team and services rendered to Tyler County Schools. ZDS worked with Tyler County Schools on the Tyler Consolidated Middle/High School HVAC Equipment Replacement Project.

ZDS Design/Consulting Services are to be commended for their patience, diligence, and HVAC engineering expertise with our recent project. The project was complicated with funding and scheduling issues, and ZDS was able to overcome these hurdles and deliver a construction project that had very little issues. Their knowledge of the building systems and project construction administration were key.

From initial project planning, design development, bidding, construction administration, and closeout, ZDS was beside Tyler County Schools to provide any necessary support needed to make this project successful. Their professional team worked closely with our staff to ensure the design accommodated all of the needs for our students and staff.

It has been a pleasure working with the staff at ZDS. I wholeheartedly recommend ZDS Design/Consulting Services for projects similar to the scope of this one.

Please feel free to contact me if you may have any questions or comments.

Sincerely,

Amanda S Kimble

Amanda S. Kimble
Director of Support Services and Facilities
Email - akimble@k12.wv.us Office - # 304-758-2145

Michael Pickens

172 Oak Street

Dunbar, WV 25064

(304) 400-9993

RE: ZDS Design/Consulting Services

I have had the privilege to work with ZDS Design/Consulting Services' principals and many of their staff since working at the School Building Authority in the 1990's in my roles at the School Building Authority to my current role as Executive Director of the Office of School Facilities at the West Virginia Department of Education.

When an emergency issue arose, they would immediately make themselves available to help. ZDS's principal, Todd Zachwieja, did not hesitate to board a helicopter during a weekend to help assess the damage to the State's school facilities when damaging floods occurred. Helicopters were the only way to reach many of the facilities because the roads had been washed away or were impassible. Anytime a challenging issue has arisen that no one knew how to resolve, ZDS has stepped up to solve the challenges. Their extensive engineering knowledge of energy efficient systems, HVAC, controls, lighting, power and plumbing systems has always been at the leading edge in the industry, providing innovative solutions that also minimize energy and operating costs. I have always considered their approach in engineering design and commissioning for buildings to be the best and would highly recommend them to anyone.

Their ability to work with the State Fire Marshal and other agencies – while guiding everyone to a practical design approach – always provided each project with the best value. They are much more than excellent design engineers; they also understand the importance of operating and maintaining equipment and have hands-on knowledge to troubleshoot and also commission to ensure our projects were a great success. Their combined engineering design and commission skills prove to be invaluable.

ZDS Design/Consulting Services was also selected to help the WV Department of Education and the School Building Authority in writing new codes and standards to raise the bar for the entire State. They were chosen because their projects were a success while we were having challenges with others. Todd Zachwieja was also asked to teach school facility staff members, and his reference books continue to be used today. I would always think of ZDS first whenever a challenge would occur, knowing I would get the best results possible.

I trust ZDS's staff in their technical expertise and their approach in solving challenging engineering issues and believe that anyone who uses them will be as satisfied as I have been. They are worth it!

Sincerely,

Michael E. Pickens

Reference Letter

ELSWICK & ASSOCIATES, LLC

To Whom It May Concern:

I am distinctly honored to provide this letter of recommendation for ZDS Design/Consulting Services to your organization. I have known ZDS's principals and many of their staff since working with Ted and Todd Zachwieja at West Virginia Institute of Technology located in Montgomery, WV, from the 1970's, while I was the Physical Plant Director there. That relationship continues through today. Their knowledge of energy efficient systems related to Heating, Ventilating, and Air-Conditioning (HVAC), Building Automation Systems (BAS), lighting, power distribution, and plumbing systems has always been at the cutting edge of the industry. They have routinely provided innovative solutions to complex design challenges while minimizing energy and operating costs and enhancing maintenance efficiency. I have always considered their approach to engineering design and commissioning systems first for higher education, hospitals and schools to be superior and I would recommend them to anyone.

Throughout my career I have continued my working relationship with Ted and Todd Zachwieja and Jim Watters while I was Director of Facilities Management at Charleston Area Medical Center (CAMC), General Division, located in Charleston, WV. During that time, they provided mechanical, electrical, and plumbing (MEP), engineering, and construction administration services for all areas of CAMC's facilities. Their knowledge of health care code and practical design approach always provided the uniqueness required for the scope of the work. They understood the importance of operating and maintaining equipment and used their hands-on knowledge to ensure all our projects were on schedule and within budget. As a matter of fact, Todd led the first energy services performance contract in West Virginia. Through Todd's leadership, CAMC saved in excess of $800,000.00 annually in energy costs and those savings were used for mechanical, electrical, and infrastructure upgrades at all three CAMC divisions. Ted, Todd, and Jim also assisted in many other projects at all CAMC divisions, including commissioning the work implemented as part of the energy savings program. Their combined engineering design and commissioning skills proved to be invaluable.

I also worked with ZDS Design/Consulting Services while I was Director of Facilities, Planning and Management at Washington & Lee University in the 1990's. They designed, acted as the construction project manager and commissioned the campus chilled water plant and distribution system to address the needs of the growing campus while fast tracking the project from start to finish in just nine months. I would always think of ZDS first whenever I was faced with a challenge, knowing that I would get the best technical expertise available.

513 Havana Dr.
Charleston, WV 25311
304.542.8877

Likewise, ZDS helped establish one of the first performance contracting programs in the State of Ohio's higher education system for Ohio University, saving the Athens campus millions annually while the savings were used for the mechanical, electrical and building automation improvements to generate the savings.

I have the utmost confidence in the technical expertise, the collaborative approach and ethical standards of ZDS Design/Consulting Services. Furthermore, these individuals are truly honorable professionals. In this regard, if you have questions or need additional information, please don't hesitate to contact me.

Sincerely,

Bill Elswick, MBA, CEO

Boyd, Gary MA, CEFP

2300 MacCorkle Ave. SE | 304 357-4871 | garyboyd@ucwv.edu

To Whom It May Concern

With well earned respect I would like to recommend ZDS as a high quality MEP design firm.

I have had multiple opportunities to work on highly technical projects with Todd Zachwieja and his team of skilled engineers. The first project that I had the opportunity to work with ZDS was a WVU project that connected several older chillers to develop a chilled water loop on the downtown campus. The project included piping through congested areas, load calculations, differential pressure and pump control, and load balancing. This project was designed to become a phased approach to a central chiller plant which is now in operation. The project was efficiently managed and the performance exceeded expectations. As the system changed and older chillers were removed from the loop, Todd always responded to questions and concerns to insure a positive outcome for the overall objective.

At present I am working with ZDS on a University of Charleston project constructing a new Innovation Center and Athletic Complex. ZDS has accommodated many twist and changes to this project. We are on track to open the new facility in December of this year. I have found Todd and his team to be highly responsive and professional.

Sincerely,

Gary L. Boyd

Boyd, Gary MA, CEFP
Director of Facilities
University of Charleston

Reference Letter

National Institutes of Health **Public Health Service**

Division of Technical Resources
Building 13, Room 201, MSC 5759
Bethesda, Maryland 20892
Phone: (301) 402-5140

Office of Research Facilities

To: E. Lon Brightbill,
Facility Dynamic Engineering (FDE)
6770 Alexander Bell Drive
Columbia, Maryland 21046

Through: Director, ORF/DTR

From: Acting Branch Chief, DTR/Technical Support Branch

Subject: Letter of Recommendation and Past Performance

It is my pleasure to provide your company with a letter of recommendation based on your present and past performances for commissioning of all types of facilities ranging from Biosafety Levels (BSL-2, 3 and 4), Mechanical/Electrical Upgrades, Penthouse Additions and hospital and healthcare facilities renovations, alterations and facility replacement projects.

I can further state, I have been involved with working directly with your firm for all of these types of projects for over 15 years now and I've been extremely satisfied with the level of expertise and performance your firm has always provided to the NIH.

To speak to specifics regarding high containment facilities at the BSL-3/4 levels, due to the security sensitive nature of the information, I can only say your leadership in the development of the commissioning planning activities from design thru final acceptances; your development and use of the facility website portals and the performance of your entire team and interaction with the safety, maintenance and operations staff along with the researchers in these facilities were and continues to be, paramount to be able to provide world-class research facilities, in which the health and safety of our world depends.

Please feel free to share the information with others and if they would like to contact me directly for more information, my contact information is provided above.

Paul D. Hawver

CITY OF CLARKSBURG
WEST VIRGINIA

SEAL OF THE CITY OF CLARKSBURG WEST VIRGINIA From 1785

OFFICE OF
CITY MANAGER

November 7, 2016

James Swiger, President and Principal-In-Charge
WYK Associates, Inc.
205 Washington Ave.
Clarksburg, WV 26301

Re: Letter of Appreciation

Dear James:

It is with great pleasure that I am writing this letter of recommendation and appreciation for James Swiger and the entire team at WYK Associates, Inc. I have thoroughly enjoyed working with Mr. Swiger and his staff. James and his team are courteous and professional and have been dedicated to even the smallest of details for each project they have completed for the City of Clarksburg. Additionally, they have ensured the projects were always on time.

Over the years, James and the staff at WYK Associates, Inc. have completed multiple projects for the City of Clarksburg including a Police Sub-Station in Laurel Lanes, three (3) Fire Stations in Clarksburg which include the Central Fire Station in downtown, and two (2) sub-stations; the East End and North View Stations, as well as designing the Jackson Square Parking Facility. Jackson Square is used for downtown parking with an outdoor venue utilized for outside events. Everything from farmers' markets, wedding receptions, holiday events and festivals like the West Virginia Italian Heritage Festival's Pasta Cook-Off. I am proud to share that WYK was awarded the AIA West Virginia Merit Award for Achievement in Architecture for this project.

I personally look forward to working with WYK Associates, Inc. again and would highly recommend them to other local governments for use on their projects.

Sincerely,

Martin Howe, ICMA-CM
City Manager

222 WEST MAIN STREET • CLARKSBURG, WEST VIRGINIA 26301 • PHONE (304) 624-1677 • FAX (304) 624-1662

Purchasing Divison
2019 Washington Street East
Post Office Box 50130
Charleston, WV 25305-0130

State of West Virginia
Centralized Expression of Interest
02 — Architect/Engr

Proc Folder: 727647

Doc Description: EOI: Third Party Peer Review Building Four

Proc Type: Central Contract - Fixed Amt

Date Issued	Solicitation Closes	Solicitation No	Version
2020-05-28	2020-06-24 13:30:00	CEOI 0211 GSD2000000005	1

BID RECEIVING LOCATION

BID CLERK
DEPARTMENT OF ADMINISTRATION
PURCHASING DIVISION
2019 WASHINGTON ST E
CHARLESTON WV 25305
US

VENDOR

Vendor Name, Address and Telephone Number:

ZDS Design/Consulting Services
281 Smiley Drive
St. Albans, WV 25177
(304) 755-0075

FOR INFORMATION CONTACT THE BUYER

Melissa Pettrey
(304) 558-0094
melissa.k.pettrey@wv.gov

Signature X Todd A. Zachwieja **FEIN #** 550735995 **DATE** 06/24/2020

All offers subject to all terms and conditions contained in this solicitation

FORM ID : WV-PRC-CEOI-001

ADDITIONAL INFORMATION:

Expression of Interest Solicitation

The Acquisitions and Contract Administration Section of the Purchasing Division is soliciting Expression(s) of Interest for the West Virginia Department of Administration, General Services Division from qualified firms to provide architectural/engineering services and other related professional services per the bid requirements, specifications and terms and conditions as attached hereto.

INVOICE TO	SHIP TO
DEPARTMENT OF ADMINISTRATION GENERAL SERVICES DIVISION 112 CALIFORNIA AVENUE, 5TH FLOOR CHARLESTON WV25305 US	DEPARTMENT OF ADMINISTRATION GENERAL SERVICES 112 CALIFORNIA AVENUE, 5TH FLOOR CHARLESTON WV 25305-0123 US

Line	Comm Ln Desc	Qty	Unit Issue
1	EOI: Third Party Peer Review Building Four		

Comm Code	Manufacturer	Specification	Model #
81101508			

Extended Description :

EOI: Third Party Peer Review Building Four

STATE OF WEST VIRGINIA
Purchasing Division

PURCHASING AFFIDAVIT

CONSTRUCTION CONTRACTS: Under W. Va. Code § 5-22-1(i), the contracting public entity shall not award a construction contract to any bidder that is known to be in default on any monetary obligation owed to the state or a political subdivision of the state, including, but not limited to, obligations related to payroll taxes, property taxes, sales and use taxes, fire service fees, or other fines or fees.

ALL CONTRACTS: Under W. Va. Code §5A-3-10a, no contract or renewal of any contract may be awarded by the state or any of its political subdivisions to any vendor or prospective vendor when the vendor or prospective vendor or a related party to the vendor or prospective vendor is a debtor and: (1) the debt owed is an amount greater than one thousand dollars in the aggregate; or (2) the debtor is in employer default.

EXCEPTION: The prohibition listed above does not apply where a vendor has contested any tax administered pursuant to chapter eleven of the W. Va. Code, workers' compensation premium, permit fee or environmental fee or assessment and the matter has not become final or where the vendor has entered into a payment plan or agreement and the vendor is not in default of any of the provisions of such plan or agreement.

DEFINITIONS:

"Debt" means any assessment, premium, penalty, fine, tax or other amount of money owed to the state or any of its political subdivisions because of a judgment, fine, permit violation, license assessment, defaulted workers' compensation premium, penalty or other assessment presently delinquent or due and required to be paid to the state or any of its political subdivisions, including any interest or additional penalties accrued thereon.

"Employer default" means having an outstanding balance or liability to the old fund or to the uninsured employers' fund or being in policy default, as defined in W. Va. Code § 23-2c-2, failure to maintain mandatory workers' compensation coverage, or failure to fully meet its obligations as a workers' compensation self-insured employer. An employer is not in employer default if it has entered into a repayment agreement with the Insurance Commissioner and remains in compliance with the obligations under the repayment agreement.

"Related party" means a party, whether an individual, corporation, partnership, association, limited liability company or any other form or business association or other entity whatsoever, related to any vendor by blood, marriage, ownership or contract through which the party has a relationship of ownership or other interest with the vendor so that the party will actually or by effect receive or control a portion of the benefit, profit or other consideration from performance of a vendor contract with the party receiving an amount that meets or exceed five percent of the total contract amount.

AFFIRMATION: By signing this form, the vendor's authorized signer affirms and acknowledges under penalty of law for false swearing (*W. Va. Code* §61-5-3) that: (1) for construction contracts, the vendor is not in default on any monetary obligation owed to the state or a political subdivision of the state, and (2) for all other contracts, that neither vendor nor any related party owe a debt as defined above and that neither vendor nor any related party are in employer default as defined above, unless the debt or employer default is permitted under the exception above.

WITNESS THE FOLLOWING SIGNATURE:

Vendor's Name: ZDS Design/Consulting Services

Authorized Signature: Todd A. Zochiireja Date: 06/24/2020

State of West Virginia

County of Kanawha, to-wit:

Taken, subscribed, and sworn to before me this 24th day of June, 2020.

My Commission expires May 21, 2025.

AFFIX SEAL HERE

Official Seal
Notary Public, State of West Virginia
Lauren M. Headley
8608 Coal River Road
St. Albans, WV 25177
My Commission Expires May 21, 2025

NOTARY PUBLIC Lauren M. Headley

ADDENDUM ACKNOWLEDGEMENT FORM
SOLICITATION NO.: GSD2000000005

Instructions: Please acknowledge receipt of all addenda issued with this solicitation by completing this addendum acknowledgment form. Check the box next to each addendum received and sign below. Failure to acknowledge addenda may result in bid disqualification.

Acknowledgment: I hereby acknowledge receipt of the following addenda and have made the necessary revisions to my proposal, plans and/or specification, etc.

Addendum Numbers Received:
(Check the box next to each addendum received)

[✓]	Addendum No. 1	[ ]	Addendum No. 6
[ ]	Addendum No. 2	[ ]	Addendum No. 7
[ ]	Addendum No. 3	[ ]	Addendum No. 8
[ ]	Addendum No. 4	[ ]	Addendum No. 9
[ ]	Addendum No. 5	[ ]	Addendum No. 10

I understand that failure to confirm the receipt of addenda may be cause for rejection of this bid. I further understand that any verbal representation made or assumed to be made during any oral discussion held between Vendor's representatives and any state personnel is not binding. Only the information issued in writing and added to the specifications by an official addendum is binding.

ZDS Design/Consulting Services
Company

Todd A. Zochirejo
Authorized Signature

06/24/2020
Date

NOTE: This addendum acknowledgement should be submitted with the bid to expedite document processing.
Revised 6/8/2012

Review of Geothermal Loop System Pumping

EXAMPLE PEER REVIEW REPORT

Review Issued –

Project No:

ZDS Design/Consulting Services

Smiley Dr., St. Albans, WV 25177 Phone (304) 755-0075 Fax (304) 755-0076

TABLE OF CONTENTS

I - EXECUTIVE SUMMARY

ZDS **Design/Consulting Services** was contracted by the to perform a peer review of the geothermal loop pumps for the and site geothermal well field. The analysis involved the review of the "geothermal side" system pumping requirements (as opposed to the "building loop side") for the facility as it pertains to total pumping capacity and good engineering practice in design.

The total pumping requirements were identified in three general areas: exterior well field, interior building loop, and heat pump branch loop geothermal system. All three receive their primary flow from the central geothermal pumps identified as P-1 and P-2 scheduled at 924 gpm with 40 ft total discharge head (TDH) each. Both were sized for full flow required to operate under peak conditions through all heat pump units. Each heat pump unit peak flow rate is listed as 84 gpm for a total plant flow rate of 924 gpm when all eleven are operating at the same time. Our analysis was based on this peak flow rate and available information from as-built conditions, submittals and past information. A site inspection was made on to visually confirm as-built conditions that impact pumping requirements. Since the well field and some portions of the work were not accessible, the analysis was based on construction photos and information provided by personnel involved with the project.

The "geothermal loop" pumping requirements are based on the calculated "farthest run" the pumps would have to circulate water where the projected "worst case" friction losses through the system would occur. We established nodes and calculated the theoretical pressure losses through the system assuming all valves and fittings were in their correct position without any unplanned obstructions in the system.

Exterior Well Field: The exterior well field was installed using SDR-11 HDPE pipe which was calculated separately from the interior of the building. The farthest well (node #1) was selected and the losses determined back to the building connection point (node #4) for the losses in the exterior well field. The "as-built" drawing , dated showing elevation points and well locations, was used to determine total distances for the well field. A single well was selected as the farthest point of all the wells and used in the analysis. The 8" HDPE pipe extended into the building with 90° elbows down then two 90° forming a u bend back up to 8" butterfly valves for the well bypass (referred to as the "candy cane".). The pipe transitions to 8" schedule 80 steel pipe after that assembly. The well field is identified in Section III.

Interior Building Loop: The geothermal building loop piping within the building includes the piping connection to the well field piping through the mechanical room. All geothermal loop piping within the building is based on schedule 80 steel pipe. Schedule 80 pipe has a smaller inside diameter than schedule 40 pipe traditionally used for a closed loop chemically treated piping system. Schedule 80 pipe requires more pump energy for comparable flow rates than schedule 40 pipe. The entire "building loop" piping is 8" except for the pipe drops to pumps P-1 and P-2, which are 6". The losses through the building loop accounts for the fitting and valves at the pump and the loss for the open three-way control valve to the dry cooler. All flow is assumed to bypass the dry cooler and flow to the well field. The losses to the dry cooler were not included in this analysis and, according to , could increase pumping energy when in operation because the 8" control valve may have to throttle to force 120 gpm of water through the dry cooler.

Heat Pump Branch Loop: The eleven heat pumps represent a significant pumping loss and were determined separately. The "end" heat pump was selected as the worst case. The analysis accounted for all the pipe fittings, valves and loss through the heat pump based on 84 gpm flow rate. A typical branch piping circuit to the heat pump from the 8" supply and piping mains includes 2.5" weldolet tap, 2.5" butterfly valve, 2.5" Y strainer, 2.5" 90° elbow, 2.5" spool with tap, 2.5" control valve (Cv=63), flanged bushing down to 2", assumed 10 feet pipe, 2" 90° elbow with heel tap for drain, assumed 3 feet of pipe, 2" FDI ball valve/strainer combo, 2' of 2" flexible stainless hose, heel tapped 90° elbow, short pipe to heat pump. Leaving heat pump is similar except a 2" Tour Anderson (TA) balancing valve replaces the 2" ball valve/strainer combo and the 2" pipe size runs to the 2.5" butterfly valve just off the 8" main. The losses through the heat pumps were obtained using the manufacturer's calculation sheet at 84 gpm flow rate.

The three areas were calculated separately to help trouble-shoot potential high loss areas within the system. The total theoretical geothermal pump head for system based upon our analysis includes the following:

Description	Total Calculated Head in Feet	Total Calculated Head in Feet
Well Field (Max to Min ID)	60.0 Max ID	72.7 Min ID
Building Loop	39.8	39.8
Branch to typical heat pump	49.3	49.3
Safety Factor of 10%	14.9	16.2
Totals	164.0	178.0

The calculated total peak pump system is 924 gpm at approximately 164 to 178 ft of head assuming 10% safety factor. The safety factor amount assumed should be reviewed by the original designers to confirm their level of safety recommended to meet their design intent. Section III contains pictures, drawings and the detailed calculations used to arrive at the values listed. The information can be reviewed by the original designers to clarify their design intent and verify accuracy of our calculated values to their knowledge of as-built conditions.

Measured data was compared to the calculated losses and was very close. A summary of the measured data to calculated data is at the beginning of Section IV. We believe the measured data was closer to 900 gpm instead of 924 gpm, which would also reduce losses. If the designer is comfortable with lower flow rates, then the measured flow rates plus a safety factor could be used in selecting a new pump.

In our professional opinion, the geothermal loop pumps were undersized and, since plans are to replace them with larger pumps, they should be selected to account for our theoretical values and additional information obtained from the field measurements. We recommend the designers review our assumptions and provide additional information that may show the pumping energy will be significantly different than our analysis.

II - ANALYSIS PROCESS

Report Goals: The building, is a part of the expansion and is currently under construction, but expected to be completed in the very near future. The goal of this report is to provide "geothermal loop pump peer review" commentary directly related to the "geothermal side" of the HVAC loads on the design documents produced by and their contracted engineer for MEP design,

Report Process: This report has been produced based on a review of the latest drawings for the project, listed as the "Addendum " set, dated , available correspondences, available submittal information for specific equipment, and review of the results from the designer's calculation dated . In addition, this report is based on conference calls, correspondences and discussions starting in with (HDPE pipe manufacturers for well field) and contractors on site through issuing this report.

An independent detailed node by node friction loss analysis was performed using available information provided by and others. The final design documents were changed due to issues that developed during construction. Therefore, an extensive detailed take-off from review of as-built conditions, construction photographs and review of the Architectural and Mechanical drawings/specifications and submittals were required. Efforts were made to correlate as much information as possible to minimize assumptions and adjust for observations made during the site visit on

The theoretical losses were also compared to field measurements provided on by and measurements provided . All data collected from field measurements and calculated losses provide a comparable conclusion. The well pumps need to be replaced with much larger pumps. The size of the larger pumps could be reduced if losses in the system are reduced. Discussions of options for reducing losses in the system are detailed in Section III.

A printout of the "peer" review geothermal pump load friction loss summaries and assumptions are included in section III of this report. The calculations on a node by node analysis are shown in Section IV of this report.

III – REVIEW OF GEOTHERMAL PUMPING SYSTEM LOSSES

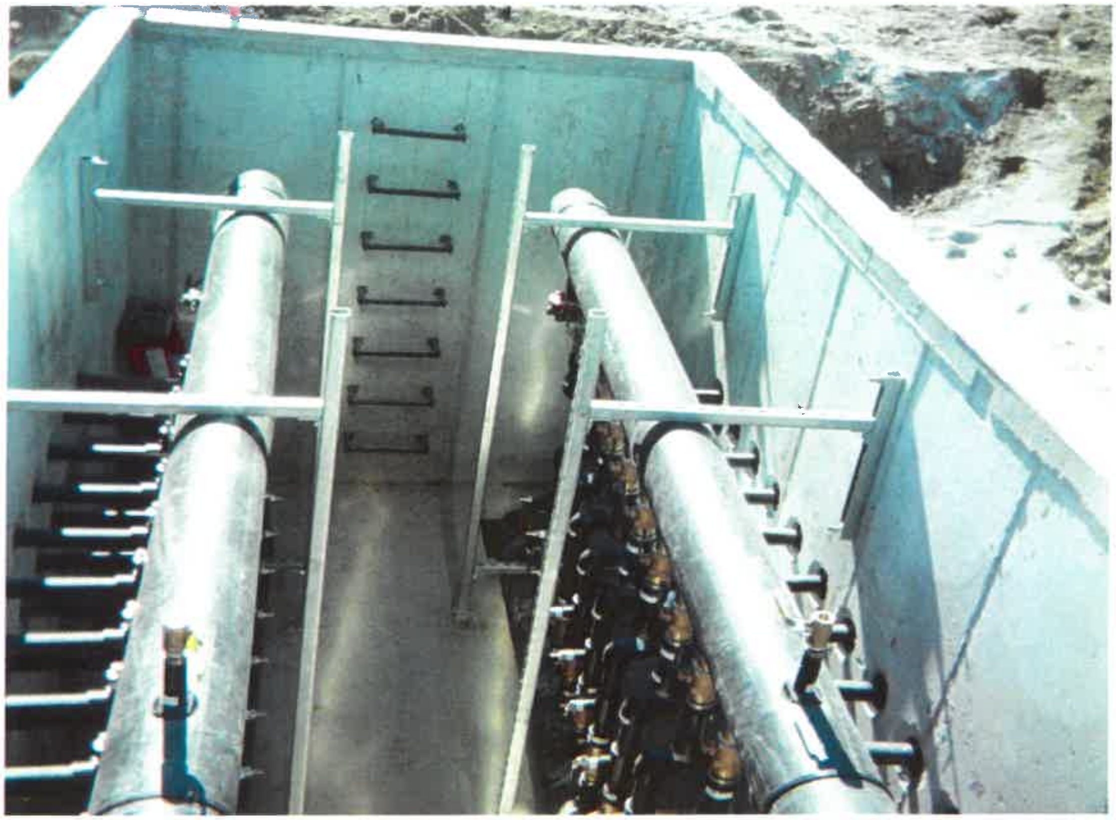
WELL FIELD ANALYSIS

Exterior Geothermal Well Field: The "geothermal pumping side" of the HVAC system can provide a total flow of 924 gpm flow through the well field. The analysis assumes the worst case of full flow through the well field. The exterior well field was installed using SDR-11 HDPE pipe, which was calculated separately from the interior of the building. Our understanding is 8" SDR 11 pipe routes from the building to a manifold vault. Multiple sets of 2" SDR 11 pipe route from the vault to manifolds. Each manifold contains four sets of 1.25" SDR 11 drops serving 500 foot deep wells with u-bend at the bottom.

We have the as-build plan view drawn to scale to check horizontal distance, but it's not clear how many valves are involved through a typical well back to the building. We assume 90 deg elbows occur at the top of each well. We also assume the total flow is spread equally between the 88 wells.

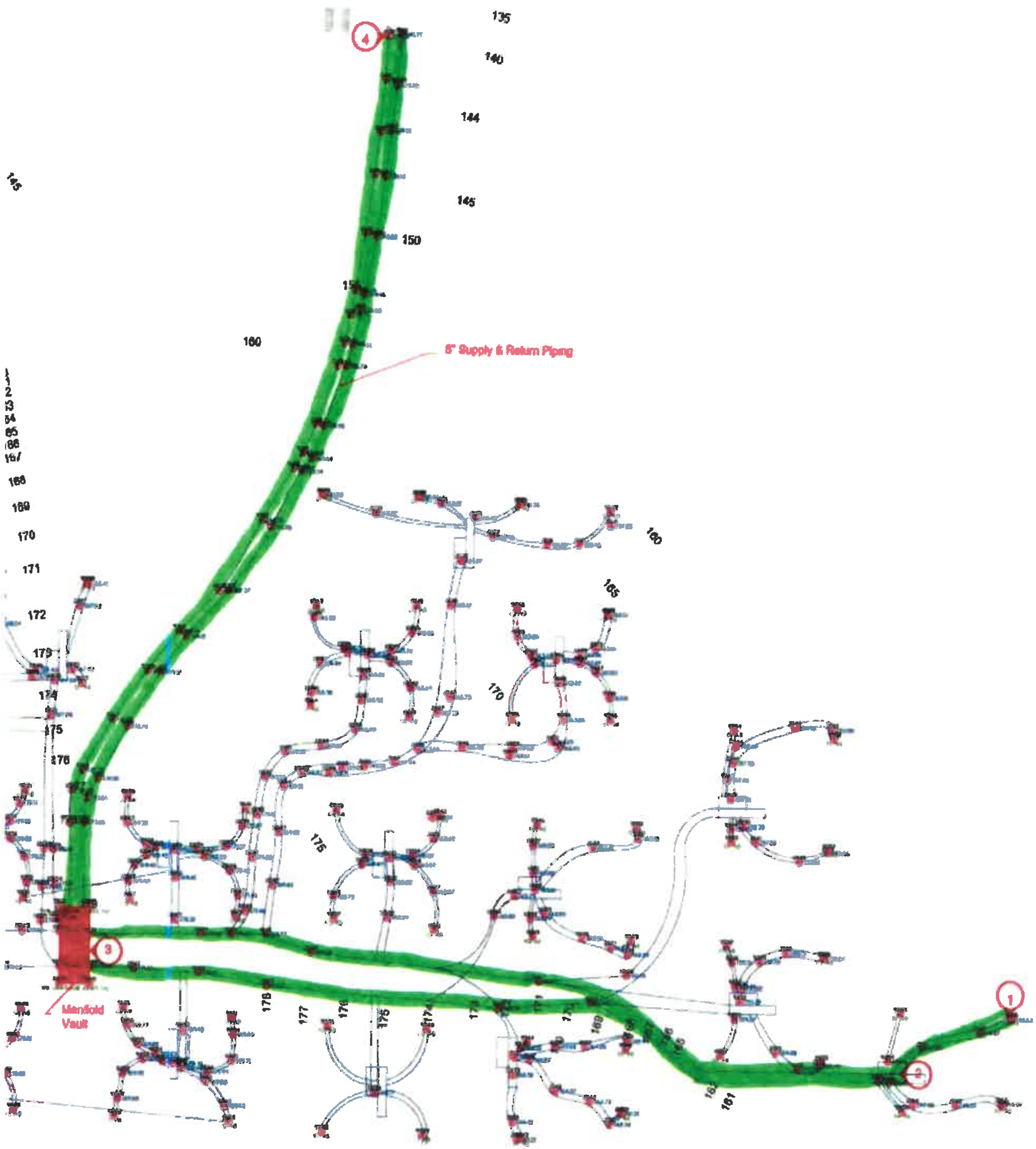
The farthest well (node #1) was selected and the losses determined back to the building connection point (node #4). The "as-built" drawing dated , showing elevation points and well locations, was used to determine total distances for the well field. The well selected was determined to be the farthest point of all the wells and used in the analysis. The following construction pictures were also reviewed for impact on pumping requirements.

Typical Node (2) Manifold of Four 1.25" HDPE Pipes from Wells to 2" HDPE Header



8" Header in Main Well Field Manifold Vault - Node (3)

8" HDPE from Well Field Node (3) to Building Node (4)



Exterior Well Field Assumed Farthest Run for Pumping Losses Nodes (1) to (4)

ZDS Design/Consulting Services

RE: Flow in HDPE Piping

You had some questions about flow in O.D. Controlled HDPE Piping which we discussed by phone today. Hopefully this will clarify some of what we talked about.

First O.D. Controlled HDPE does have some tolerance in its manufacture which all compounds into the I.D. which is what you are interested in for flow calculations. Both the O.D. itself and the walls can vary, so I am showing what amounts to the largest ID (using max. O.D. from the specs and min. wall thickness) as well as the smallest ID (using min. O.D. and maximum wall thickness). I believe an average ID is usually calculated using the target O.D. and an average O.D. which is 6% more than the minimum. (The specs for the walls can vary about 12% so this is half of that.) Below is a chart for 1 ¼", 2", and 8" IPS SDR 11, which I believe is what you are working with on this project. I have used ASTM D 3035 for the small pipe and ASTM F 714 for the 8" IPS.

Size	O.D.	O.D. Tol.	Min. Wall.	Max. Wall	Min. I.D.	Max I.D.	AVG
1 ¼"	1.660"	+/-.005"	.151"	.171"	1.313"	1.363"	1.34"
2"	2.375"	+/-.006"	.216"	.242"	1.885"	1.949"	1.92"
8"	8.625"	+/-.039"	.784"	.878"	6.830"	7.096"	6.96"

As for acceptable flow velocities in HDPE, the Plastic Pipe Institute says that, in optimum conditions, flows above 25 ft/sec may be acceptable. I have seen other statements that if abrasive contamination is a concern, then flows should be kept below about 6 ft/sec to minimize erosion of the plastic.

I hope this answers your questions, so that you may complete your project, but if I can be of further help, please feel free to contact me.

Sincerely:

HDPE piping inside diameter can vary and still meet industry standards as noted in the letter on the previous page from , the manufacturer of the HDPE pipe used on the project. A 12% variation in pipe wall thickness can occur. Most HDPE manufactures publish a single value for inside diameters, but actual values can vary. Since losses could vary in the well field depending upon the actual inside diameter of the pipe used, both the maximum and minimum inside diameter losses were calculated assuming the full 924 gpm flow through the well field. Realistically the actual losses likely are in between the two values. Both are included for comparison.

Commentary:

According to the , letter from the designer, "*the flow required at the well field for heat rejection is 672 gpm, which exceeds the flow required for heat absorption. The flow required to the well field with nine heat pumps operating in the cooling mode is 756 gpm. With the tenth heat pump running in heating mode, the required flow to the well field will be less than 756 gpm, since the tenth pump is operating in the opposite mode as the first nine. The maximum flow required through the heat pump system is 840 gpm. Each heat pump has a full condenser flow of 84 gpm. The installation of the well bypass valve allows for an offset in the flow going out to the well field and the flow through the heat pumps.*"

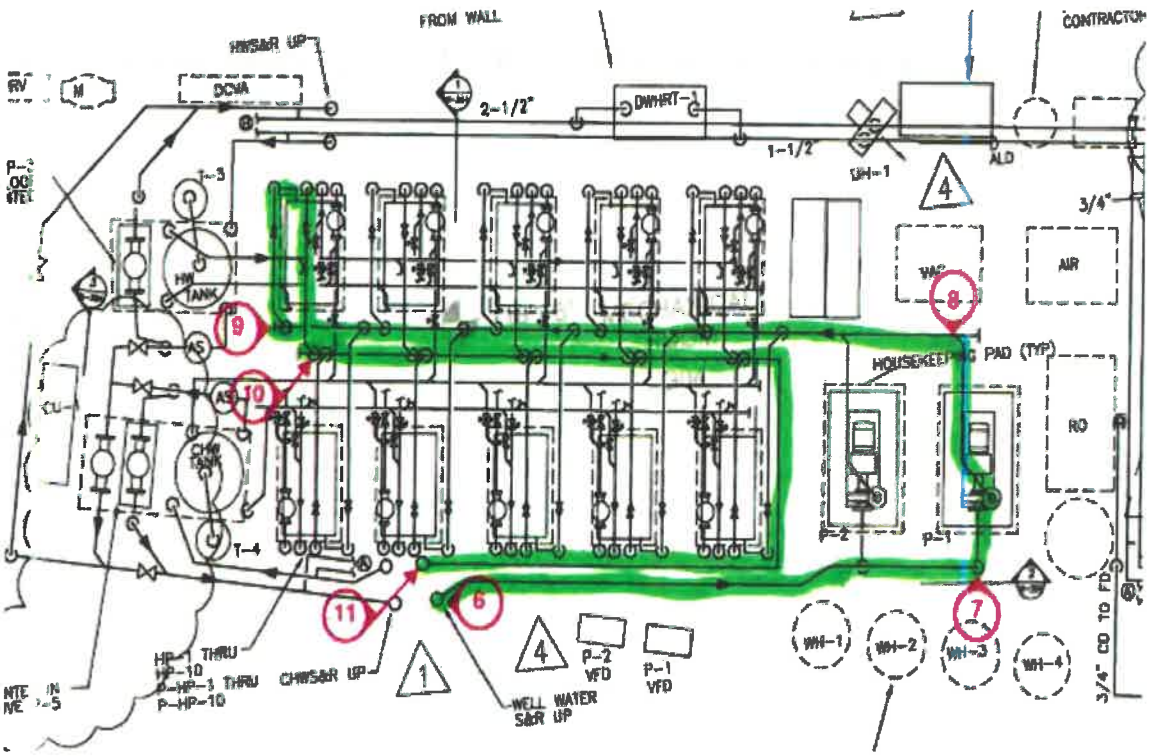
Our analysis was based on all eleven heat pumps operating with a total flow rate of 924 gpm flowing through the well field. If a portion of the flow is diverted as proposed by the designer, the pressure losses through the well field could reduce to 36 ft head to 43 ft head depending upon actual HPDE pipe inside dimensions, which is within the well pressure losses stated by the designer. However, the losses through the 8 x 4 diverting valves at the dry cooler heat exchange would increase head loss and the total pump energy is still likely near the values calculated. If full flow of 924 gpm is used the pressure loss increase to from 60 feet of head to 72.7 feet of head which is much more than currently designed.

The well field appears to be nearly 40 feet above the low building entrance point of the piping which can allow for air to be trapped. Automatic air vents are shown installed at the high points of the manifold system, which should address this potential problem if working properly. Testing data provided by the well field contractor also shows the exterior wells were flushed with water at sufficient velocity to remove air from the system.

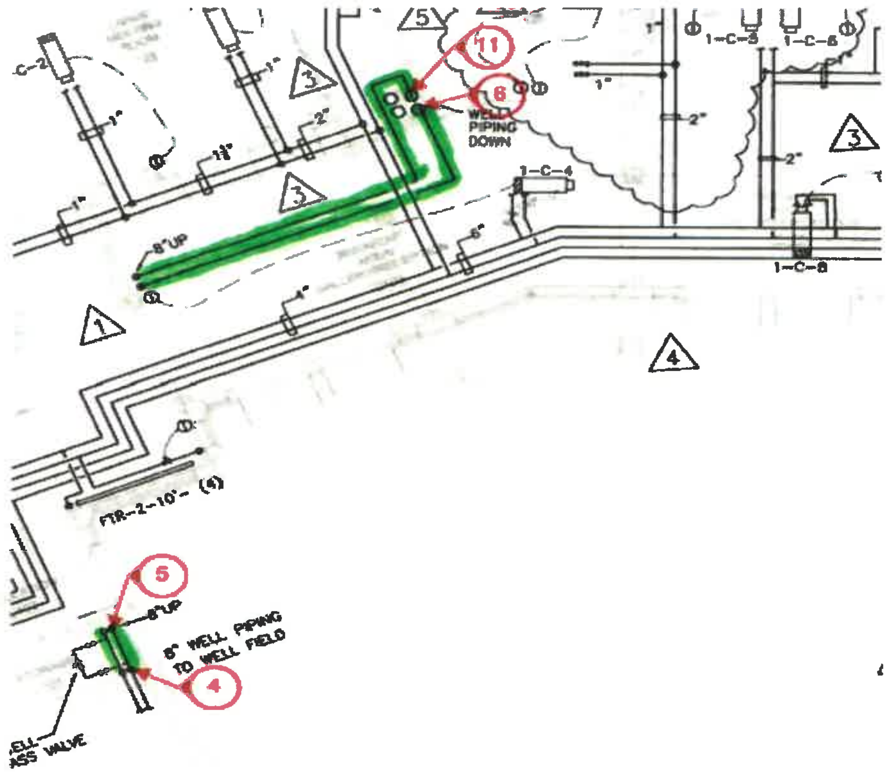
BUILDING LOOP LOSS ANALYSIS

Central Heating & Cooling Plant: The "geothermal pumping side" of the HVAC system consists of eleven (11) geothermal heat pump units rated for 84 gpm flow each for a total flow of 924 gpm. Each heat pump unit can provide either heating or cooling through a control valve arrangement but not both at the same time. A dry cooler is piped in the building loop to reject excess heat during off-peak electric usage periods which also has some impact on the geothermal loop pumping requirements. The flow through the dry cooler heat exchanger was assuming zero for the pumping calculations as the "worst case" with the three-way control valve in the full bypass position.

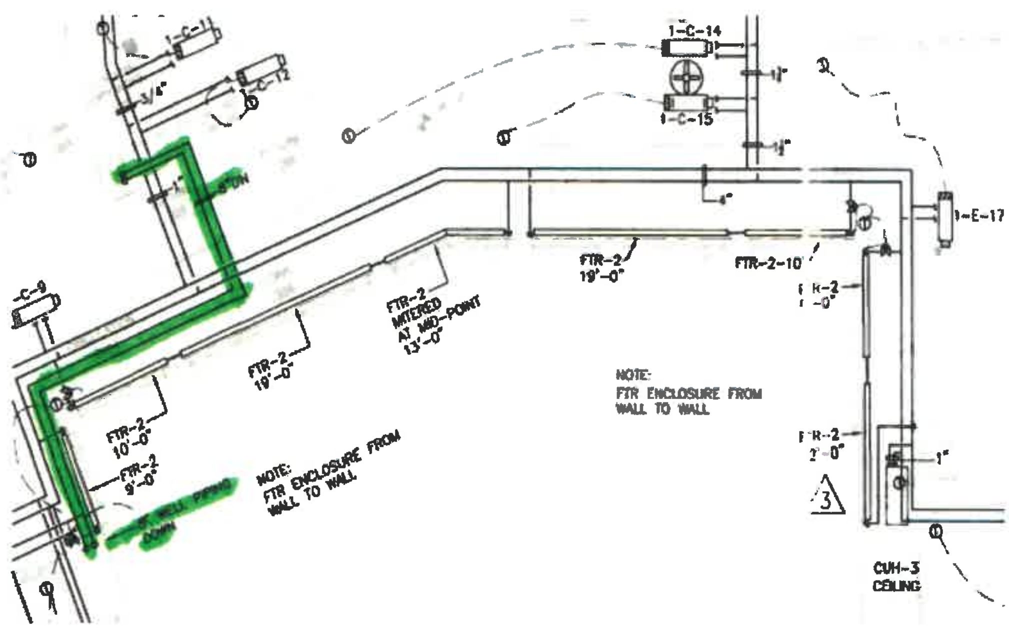
The primary building loop piping consists of two pumps sized for 100% redundancy so only one pump is required to operate under peak loads. The other pump serves as a backup. The pumps were sized for 100% peak flow but did not appear to account for the total friction losses at peak flow conditions. The primary building loop consists of 8" schedule 80 steel pipe except for reductions to 6" schedule 80 pipe to each loop pump (P-1 and P-2). The 8" schedule 80 steel pipe connects to SDR-11 HDPE pipe at the building exit heading to the well field. An 8" steel pipe reverse return header was installed at the heat pumps. Each heat pump was designed for a 2.5" branch pipe to serve the heat pump. The pipe connections to the heat pumps were 2". The transition from 2.5" to 2" was made well before the heat pumps, which increased friction losses. The pump friction losses for the heat pump branch (nodes 9 to node 10) were calculated separately from the building loop friction losses. The building loop loss calculations are from the well field connection point at node 4 to equipment room node 9 then starting again at equipment room node 10 to equipment room node 11 to node 4. The green highlighted lines over the pipe routing reflect the longest run for the geothermal pump loss analysis.



Building Loop in Mechanical Room - From DWG



Building Loop First Floor East Wing - From DWG



Building Loop Second Floor East Wing - From DWG

HEAT PUMP BRANCH LOOP LOSS ANALYSIS

Both the building loop and heat pump loop use schedule 80 steel pipe and fittings. Charts to determine inside dimensions that were used in the pump loss analysis are shown below.

PIPING 8-81

DIMENSIONAL AND CAPACITY DATA — SCHEDULE 80 STEEL PIPE

Diameter, In.			Wall Thickness, In.	Cross-Sectional Area, Sq. In.			Weight per Foot, Lb.		
Nominal	Actual Inside	Actual Outside		Outside	Inside	Metal	Of Pipe	Of Water in Pipe	Of Pipe and Water
1/8	0.215	0.405	0.095	0.129	0.036	0.093	0.314	0.016	0.330
1/4	0.302	0.540	0.119	0.229	0.072	0.157	0.535	0.031	0.566
3/8	0.423	0.675	0.126	0.358	0.141	0.217	0.738	0.061	0.799
1/2	0.546	0.840	0.147	0.554	0.234	0.320	1.087	0.102	1.189
3/4	0.742	1.050	0.154	0.866	0.433	0.433	1.473	0.213	1.686
1	0.957	1.315	0.179	1.358	0.719	0.639	2.171	0.312	2.483
1 1/4	1.278	1.660	0.191	2.164	1.283	0.881	2.996	0.555	3.551
1 1/2	1.500	1.900	0.200	2.835	1.767	1.068	3.631	0.765	4.396
2	1.939	2.375	0.218	4.431	2.954	1.477	5.022	1.280	6.302
2 1/2	2.323	2.875	0.276	6.492	4.238	2.254	7.661	1.830	9.491
3	2.900	3.500	0.300	9.621	6.605	3.016	10.252	2.870	13.122
3 1/2	3.364	4.000	0.318	12.568	8.890	3.678	12.505	3.720	16.225
4	3.826	4.500	0.337	15.903	11.496	4.407	14.983	4.970	19.953
5	4.813	5.563	0.375	24.308	18.196	6.112	20.778	7.940	28.718
6	5.761	6.625	0.432	34.474	26.069	8.405	28.573	11.300	39.873
8	7.625	8.625	0.500	58.426	45.666	12.760	43.388	19.800	63.188
10	9.564	10.750	0.593	90.79	71.87	18.92	64.400	31.130	95.530

Schedule 80 Steel Pipe Inside Dimensions

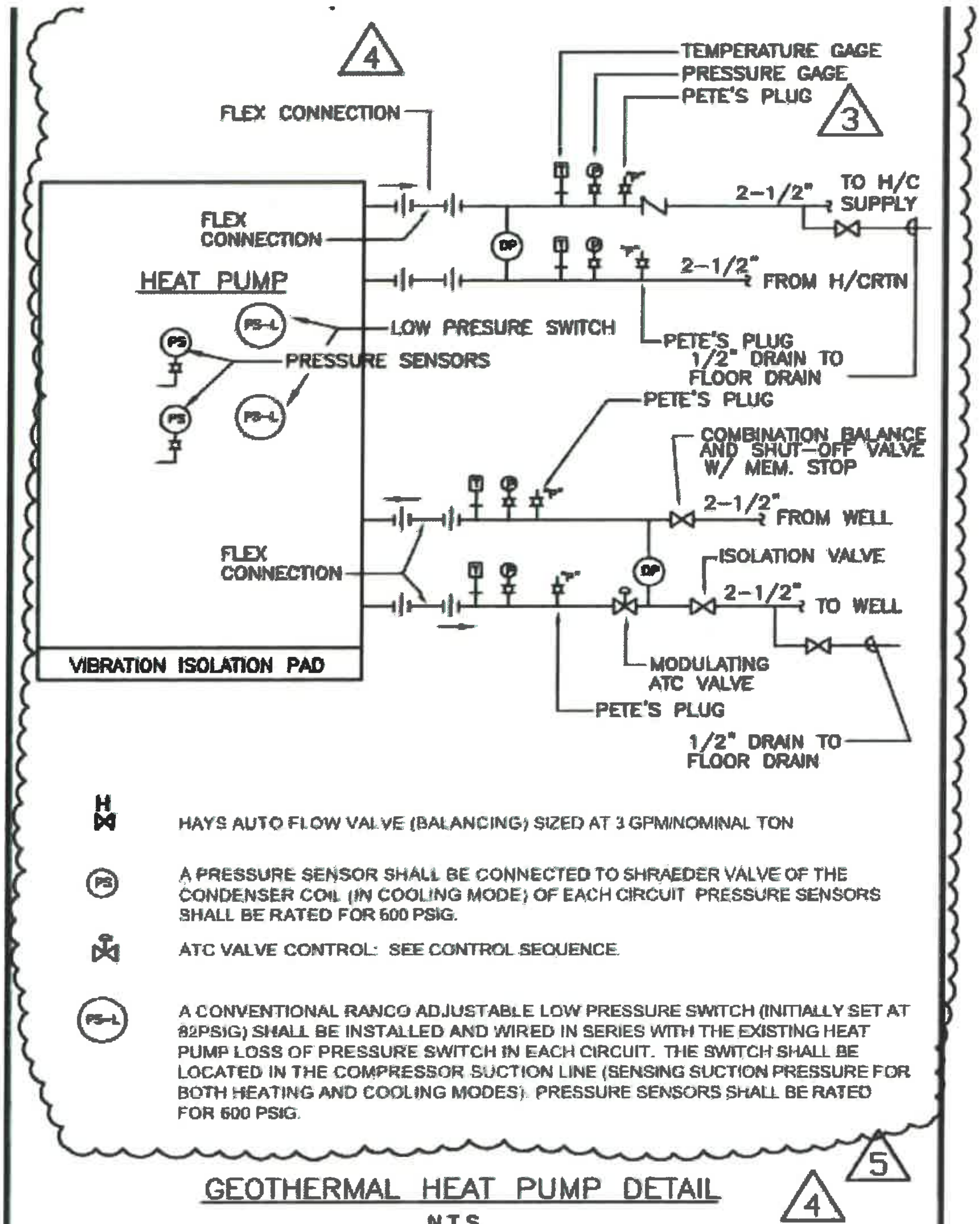
EQUIVALENT RESISTANCE OF VALVES AND FITTINGS

Nominal Pipe Diameter, Inches	Valve or Fitting									
	Globe Valve, Open	Gate Valve				Angle Valve, Open	Close Return Bend	Tee		Ordinary Entrance‡
		¾ Closed	½ Closed	¼ Closed	Open			Through Run	Through Side†	
	Equivalent Resistance, Feet of Pipe									
½	16	40	10	2	0.3	9	4	1.0	4	0.9
¾	22	55	14	3	0.5	12	5	1.4	5	1.2
1	27	70	17	4	0.6	15	6	1.7	6	1.5
1¼	37	90	22	4	0.8	18	8	2.3	8	2.0
1½	44	110	28	6	0.9	21	10	2.7	9	2.4
2	55	140	35	7	1.2	28	13	3.5	12	3.0
2½	65	160	40	8	1.4	32	15	4.2	14	3.3
3	80	200	50	10	1.6	41	18	5.0	17	4.5
3½	100	240	60	12	2.0	50	21	6.0	19	5.0
4	120	275	69	14	2.2	55	25	7.0	21	6.0
5	140	325	81	16	2.9	70	30	8.5	27	7.5
6	160	400	100	20	3.5	80	36	10.1	34	9.0
8	220	525	131	26	4.5	110	50	14.0	44	12.0
10	—	700	175	35	5.5	140	60	17.0	55	15.0
12	—	800	200	40	6.5	160	72	19.0	65	16.5
14	—	950	238	48	8.0	190	85	23.0	75	20.0
16	—	1100	272	52	9.0	220	100	26.0	88	22.0
18	—	1300	325	65	10.0	250	115	30.0	110	25.0

Nominal Pipe Diameter, Inches	Valve or Fitting									
	Sudden Contraction§			Borda Entrance	Reducing Tee*		90° Elbow			45° Elbow
	D/d=4	D/d=2	D/d=4/3		D/d=2	D/d=4/3	Standard	Medium Sweep	Long Sweep	
	Equivalent Resistance, Feet of Pipe									
½	0.8	0.6	0.3	1.4	1.5	1.3	1.5	1.3	1.0	0.8
¾	1.0	0.8	0.5	1.9	2.0	1.8	2.0	1.8	1.4	1.0
1	1.3	1.0	0.6	2.5	2.6	2.4	2.6	2.4	1.7	1.3
1¼	1.6	1.3	0.8	3.5	3.5	3.1	3.5	3.1	2.3	1.6
1½	2.0	1.5	0.9	4.0	4.5	3.7	4.5	3.7	2.7	2.0
2	2.5	1.9	1.2	5.0	5.3	4.5	5.3	4.5	3.5	2.5
2½	3.0	2.2	1.4	6.0	6.3	5.5	6.3	5.5	4.2	3.0
3	3.7	2.8	1.6	7.5	8.0	6.9	8.0	6.9	5.0	3.7
3½	4.4	3.3	2.0	9.0	9.5	8.0	9.5	8.0	6.0	4.4
4	5.0	3.7	2.2	11.0	11.5	9.5	11.0	9.5	7.0	5.0
5	6.0	4.7	2.9	12.0	12.5	12.0	13.0	12.0	8.5	6.0
6	7.5	5.6	3.5	15.0	16.0	14.0	16.0	14.0	10.1	7.5
8	11.0	7.2	4.5	19.0	20.0	18.0	20.0	18.0	14.0	10.0
10	13.0	9.5	5.5	24.0	25.0	22.0	25.0	22.0	17.0	13.0
12	15.0	11.0	6.5	29.0	31.0	26.0	31.0	26.0	19.0	—
14	17.0	12.5	8.0	34.0	36.0	30.0	36.0	30.0	23.0	—
16	19.0	15.0	9.0	38.0	40.0	35.0	40.0	35.0	26.0	—
18	21.0	16.5	10.0	43.0	45.0	40.0	45.0	40.0	30.0	—

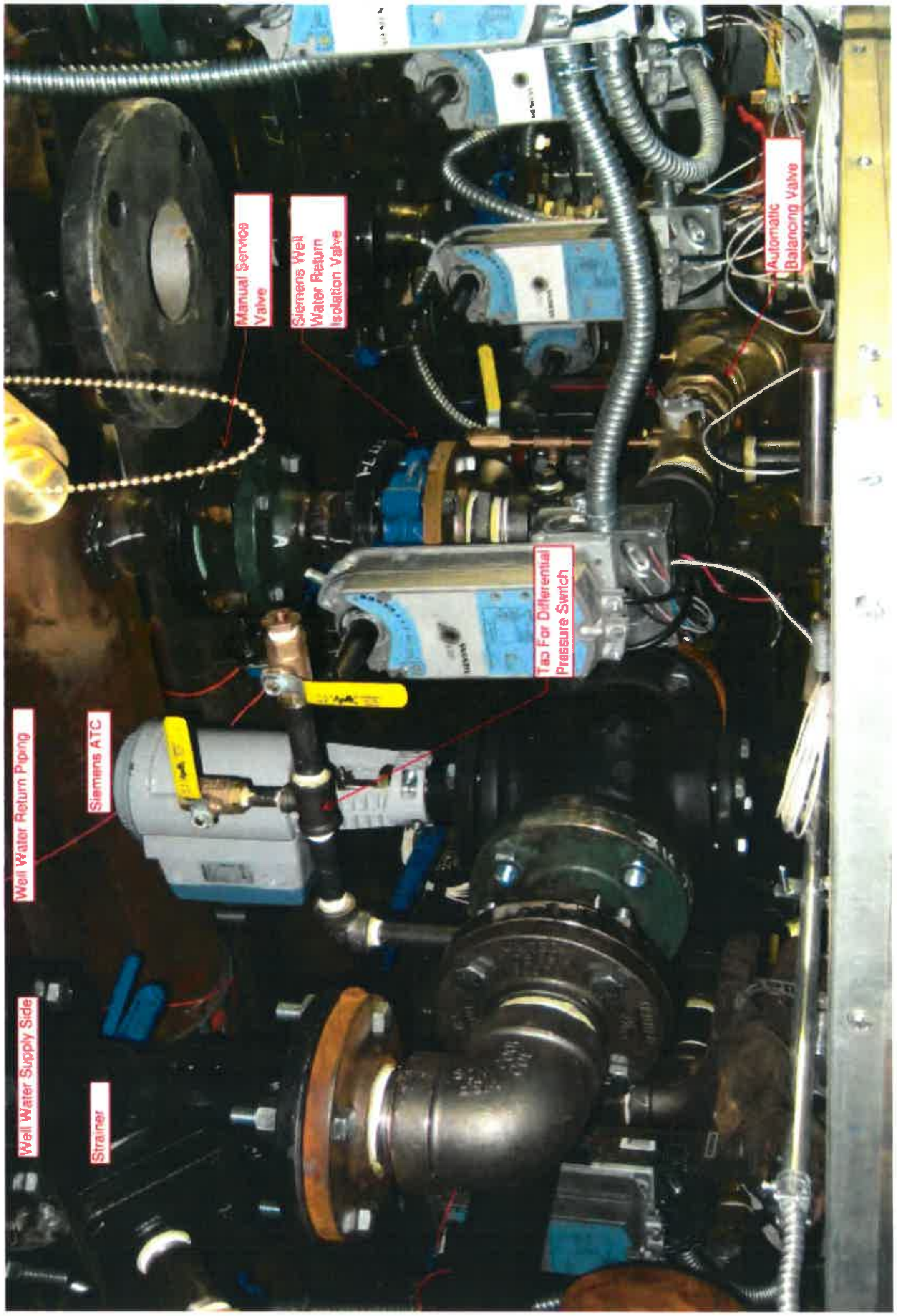
* For flow making 90° turn. ‡ Into pipe of given diameter from tank, etc.
† For run of tee. Use pipe size of small diameter.
§ Use pipe size of small diameter. For Sudden Enlargements, d/D=¼, values are same as for Reducing Tee, D/d=2; d/D=½, values are same as for Tee, Through Run; d/D=¾, values are same as for Sudden Contraction, D/d=4/3.

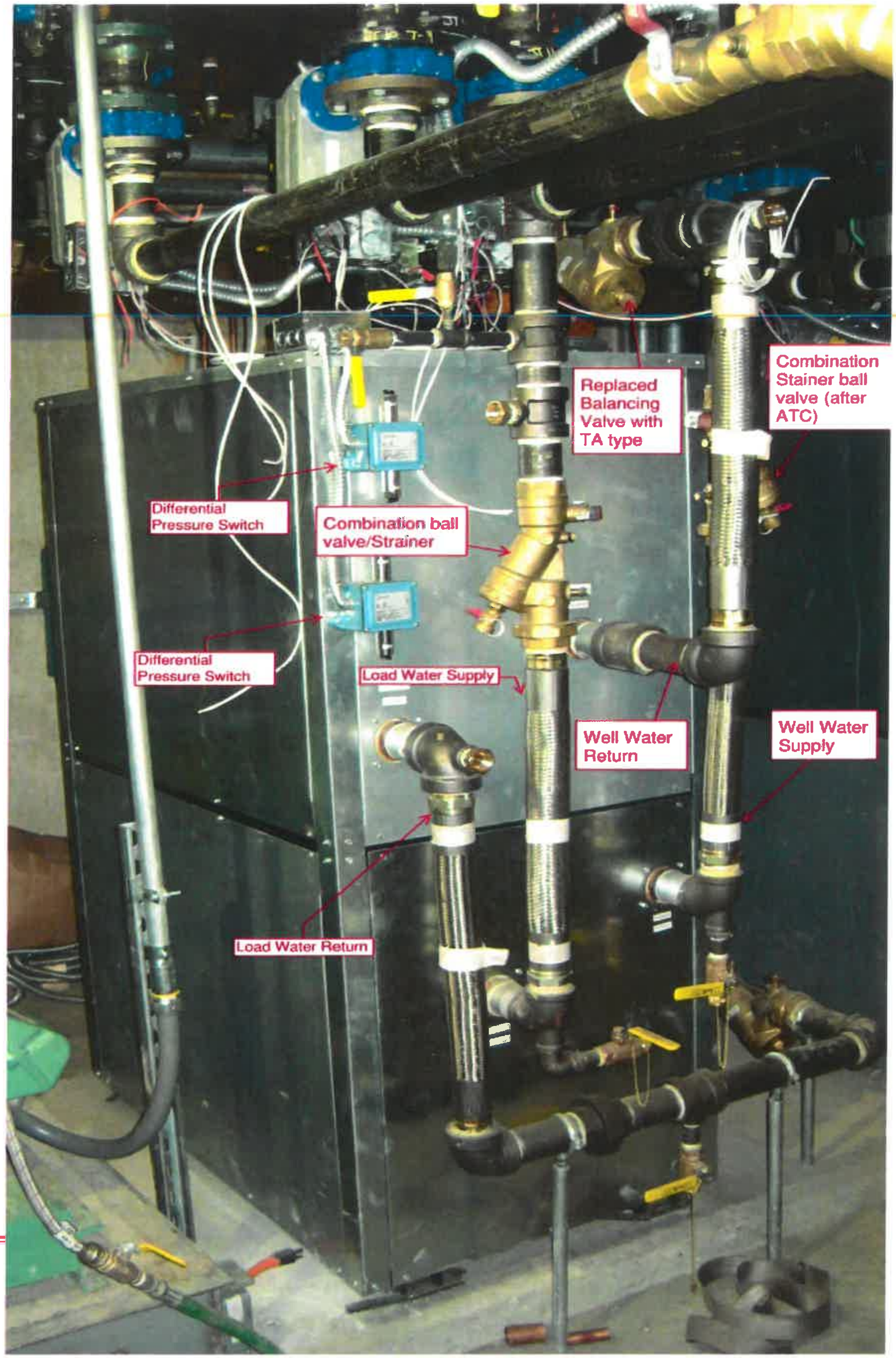
Heat Pump Equipment Branch: The piping design intent was clarified by the design team as noted on drawing . dated as shown below. The pictures that follow show as-built conditions which differ from this sketch.



GEOTHERMAL HEAT PUMP DETAIL

N.T.S.


Manual Service Valve
Siemens Well Water Return Isolation Valve
Automatic Balancing Valve
Tap For Differential Pressure Switch
Siemens ATC
Well Water Return Piping
Well Water Supply Side
Strainer


Replaced Balancing Valve with TA type
Combination Stainer ball valve (after ATC)
Differential Pressure Switch
Combination ball valve/Strainer
Differential Pressure Switch
Load Water Supply
Well Water Return
Well Water Supply
Load Water Return

The geothermal heat pump diagram differs from as-built conditions when compared to the photos. The major difference is where the pipe size changes from 2.5" to 2" in the branch circuit. The pipe reduces at the two-way control valve to 2" (which was installed on the supply side instead of return shown on the diagram) and changes to 2" after the butterfly valve installed just before the 8" return header. A strainer was also installed upstream of the control valve and a combination ball valve/strainer was installed after the control valve that were not shown on the detail.

Commentary:

Clarify the design intent where the pipe should transition from 2.5" to 2". If the pipe reduction occurs at the heat pump connection points, the friction losses would be significantly less. Schedule 80 pipe at this pipe size instead of schedule 40 commonly used also increases friction losses which increase pumping requirements. Consider eliminating the combination ball valve/strainer which appears to be redundant since an isolation valve and strainer are upstream of this assembly, which can save pump energy.

2" Tour Anderson Balancing Valve: The original FDI auto-flow valve was replaced with a 2" Tour Anderson balancing valve which reduces pipe losses some when compared with the original FDI combination auto flow valve/ball valve. The FDI manufacturer's literature was reviewed to verify expected losses for this type of assembly. The pressure losses were reduced from over 14 feet of head to expected pressure loss of 11.29 feet of head at 84 gpm through this fitting. Ideally all the fittings in the heat pump branch loop would be 2.5" instead of many installed at 2".

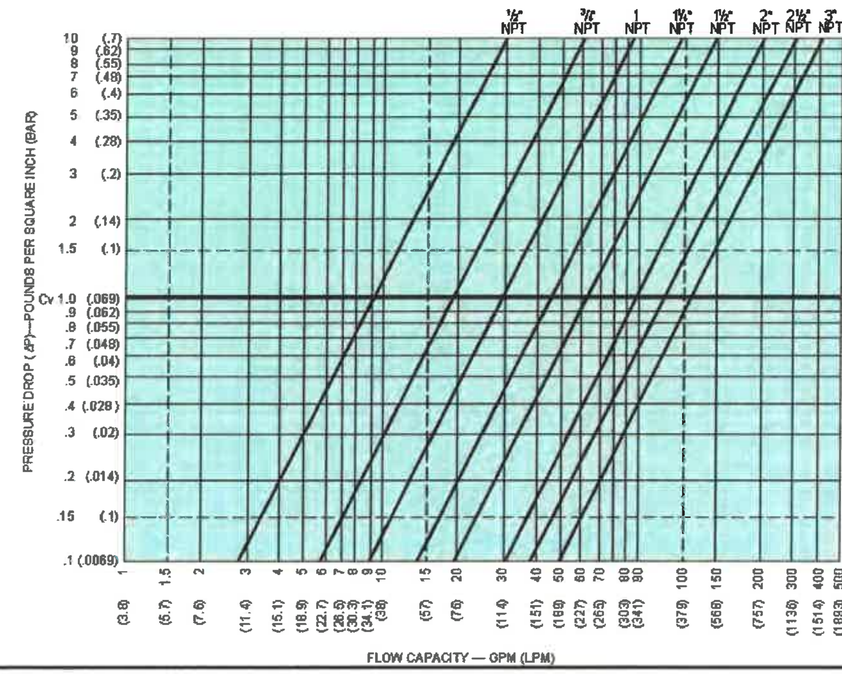
Heat Pump Unit: The manufacturer's calculation spreadsheet was used and it was determined that the 84 gpm flow rate in heating mode was more than cooling mode. This program was also used by the design engineers in their information. Heating mode shows 14.0 feet of head drop at 84 gpm. Cooling was about 1.5 feet lower. The chart shown below indicates an expected pressure loss of 14 feet of head at 84 gpm though the heat pump.

	Heating
Source Water Flow (GPM)	84.0
Load Water Flow (GPM)	64.0
Source Entering Water Temp (F)	70.0
Load Entering Water Temp (F)	70.0
Source Percent Propylene Glycol	0.0
Load Percent Propylene Glycol	0.0
	Heating
Source Pressure Drop (FOH)	14.0
Load Pressure Drop (FOH)	8.2

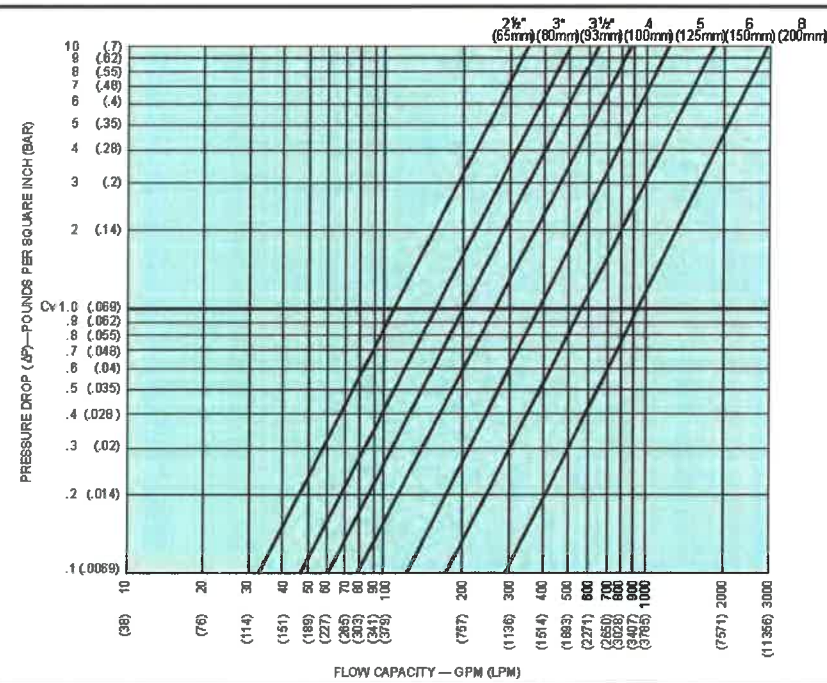
Pressure Losses for Heat Pump Based on 84 GPM shows 14 feet of head

Capacities – Water Flow vs Pressure Drop

Screwed End Y-Strainers



Flanged End Y-Strainers



Y-Strainer Losses used in Calculations - note difference between 2" and 2.5"

GEOTHERMAL PUMP LOSSES ASSUMPTIONS

The pump loss analysis report is included in both hard copy and an electronic PDF file for review. The major assumptions used in the loss analysis are embedded in the Excel spreadsheets included in Section IV or highlighted in this report. Other assumptions include the following:

1. Friction losses in system are based on using the Colebrook Formula to determine the friction factor (f) based on pipe internal diameter (d') and Reynolds Number. Information referenced is from "Handbook of Polyethylene Pipe" second edition published by the Plastic Pipe Institute.

The Colebrook formula is:

(2-6)
$$\frac{1}{\sqrt{f}} = -2\log_{10}\left\{\frac{\varepsilon}{3.7d'} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right\}$$

For Formulas 2-5 and 2-6, terms are as previously defined, and:

ε = absolute roughness, ft. (see Table 2-1)

R_e = Reynolds number, dimensionless (see Equation 2-5)

2. The Darcy-Weisbach formula is used for friction head loss in feet of water. Information referenced is from "Handbook of Polyethylene Pipe" second edition published by the Plastic Pipe Institute.

The Darcy-Weisbach formula is:

(2-3)
$$h_f = f\frac{LV^2}{d'2g}$$

WHERE

h_f = friction (head) loss, ft. of liquid

L = pipeline length, ft.

d' = pipe inside diameter, ft.

V = flow velocity, ft/sec.

f = friction factor (dimensionless, but dependent upon pipe surface roughness and Reynolds number)

g = constant of gravitational acceleration (32.2ft/sec²)

3. Information referenced is from "Handbook of Polyethylene Pipe" second edition published by the Plastic Pipe Institute.

The equivalent length of pipe to be used to estimate the friction loss due to fittings may be obtained by Eq. 2-9 where L_{EFF} = Effective Pipeline length, ft; D is pipe bore diameter in ft.; and K' is obtained from Table 2-2.

(2-9) $L_{EFF} = K'D$

TABLE 2-2
Representative Fittings Factor, K', To Determine Equivalent Length of Pipe

Piping Component	K'
90° Molded Elbow	40
45° Molded elbow	21
15° Molded Elbow	6
90° Fabricated Elbow (3 or more miters)	24
90° Fabricated Elbow (2 miters)	30
90° Fabricated Elbow (1 miters)	60
60° Fabricated Elbow (2 or more miters)	25
60° Fabricated Elbow (1 miters)	16
45° Fabricated Elbow (2 or more miters)	15
45° Fabricated Elbow (1 miters)	12
30° Fabricated Elbow (2 or more miters)	8
30° Fabricated Elbow (1 miters)	8
15° Fabricated Elbow (1 miters)	6
Equal Outlet Tee, Run/Branch	60
Equal Outlet Tee, Run/Run	20
Globe Valve, Conventional, Fully Open	340
Angle Valve, Conventional, Fully Open	145
Butterfly Valve, >8", Fully Open	40
Check Valve, Conventional Swing	135

- K values are based on Crane Technical Paper No 410-C

- K value for Molded Elbows is based on a radius that is 1.5 times the diameter.

- K value for Fabricated Elbows is based on a radius that is approximately 3 times the diameter.

4. Miscellaneous piping lengths were obtained from data on the drawings using our experience and engineering judgment.

Section IV

CALCULATIONS OF

GEOTHERMAL PUMPING

SYSTEM LOSSES

PROJECT

DATE

Sub Total Head Losses in Well Field

	Max ID	Min ID	
Calculated	60.0 ft-h2o	72.7 ft-h2o	<= See spreadsheets for details

Measured 54.7 ft-h2o from information at bypass "candy cane"

Sub Total Head Losses in Building Loop

Calculated 39.8 ft-h2o <= See spreadsheet for details

Measured 37.0 ft-h2o based on :otal less Well Field/Heat Pump

Sub Total Head Losses in Heat Pumps

Calculated 49.3 ft-h2o <= See spreadsheet for details

Measured Pump Losses Across Heat Pumps Branches

Unit No.	**GPM**	**Entering & Leaving PSI**	**PSI**	**Delta PSI**	**Heat Pump Branch Loss**
#1	76.0	110.5	87.30	23.2	53.6 ft-h2o
#2	82.0	111.9	99.50	12.4	28.6 ft-h2o
#3	85.0	108.1	93.60	14.5	33.5 ft-h2o
#4	80.0	106.8	84.60	22.2	51.3 ft-h2o
#5	**82.0**	**110.3**	**85.00**	**25.3**	**58.4 ft-h2o** *
#6	80.0	107.2	85.80	21.4	49.4 ft-h2o
#7	86.0	106.8	86.00	20.8	48.0 ft-h2o
#8	85.0	105.3	87.40	17.9	41.3 ft-h2o
#9	83.9	107.5	83.90	23.6	54.5 ft-h2o
#10	80.0	106.8	84.60	22.2	51.3 ft-h2o
#11	83.8	104.2	83.80	20.4	47.1 ft-h2o
	903.7				

Heat Pump #5 Branch Circuit is "worst case" for pumping

Calculated		**Max ID**	**Min ID**
Total Head Loss		149.1 ft-h2o	161.8 ft-h2o
Safety Factor	10%	14.9 ft-h2o	16.2 ft-h2o
Total Calculated		**164.0 ft-h2o**	**178.0 ft-h2o**
		71.0 psig	77.1 psig

Safety factor account for some loading on strainers and varying losses on heat pumps

Total Pump Loss at P-1/P-2 Header from Measured Data

Measured 150.2 ft-h2o excludes pump P-1/P-2 fitting losses

Measured 886.5 GPM

WELL FIELD MIN PIPE ID LOOP HEAD LOSSES

PROJECT	**Geothermal Pump Peer Review**	DATE
PIPE TYPE	High Density Polyethylene Piping SDR11. See Note 3	
FLUID KINEMATIC VISCOSITY	1.664E-05 ft2/sec based on water temperature of 40°F and a Specific Gravity of 1.	
PIPE ABSOLUTE ROUGHNESS	0.000005 feet: See Note 2	
TOTAL SYSTEM FLOW BASED ON 11 HEAT PUMPS IN OPERATION	924.0 gpm	
INDIVIDUAL WELL FLOW BASED ON 88 WELLS @ EQUAL FLOW	10.5 gpm	

NODES	DESCRIPTION	NOMINAL SIZE	INSIDE DIAMETER	FLOW	VELOCITY	REYNOLDS NUMBER	FRICTION FACTOR	See Note 1 LENGTH OR K' factor	Darcy-Weisbach SECTION LOSS	CUMULATIVE LOSS
2 to 1	From 4 well manifold to top of well	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	40	0.97 ft-h2o	1.0 ft-h2o
1	Elbow down into the well	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	40	0.11 ft-h2o	1.1 ft-h2o
1	Straight pipe to bottom of well	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	500	12.09 ft-h2o	13.2 ft-h2o
1	Elbow to riser at bottom of well	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	40	0.11 ft-h2o	13.3 ft-h2o
1	Elbow at Bottom of riser up out of well	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	40	0.11 ft-h2o	13.4 ft-h2o
1	Straight pipe to top of well	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	500	12.09 ft-h2o	25.5 ft-h2o
1	Elbow at top of well	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	40	0.11 ft-h2o	25.6 ft-h2o
1 to 2	From top of well to 4 well manifold	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	40	0.97 ft-h2o	26.5 ft-h2o
2	Assumed straight pipe entering 4 well manifold	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	6	0.15 ft-h2o	26.7 ft-h2o
2	Elbow up to 4 well manifold	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	40	0.11 ft-h2o	26.8 ft-h2o
2	Minimum straight pipe up to manifold 15 pipe Diameters	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	1.6	0.04 ft-h2o	26.8 ft-h2o
2	Weldolet connection assume losses = to Tee connection	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	60	0.16 ft-h2o	27.0 ft-h2o
2	4 well manifold assumed length.	2.00 inches	1.885 inches	42.0 gpm	4.83 fps	4.559E+04	0.0217	8	0.40 ft-h2o	27.4 ft-h2o
2 to 3	Straight Piping from 4 well manifold vault	2.00 inches	1.885 inches	42.0 gpm	4.83 fps	4.559E+04	0.0217	243	12.16 ft-h2o	39.5 ft-h2o
3	Assumed straight pipe entering Vault at node 3	2.00 inches	1.860 inches	42.0 gpm	4.96 fps	4.620E+04	0.0216	6	0.32 ft-h2o	39.9 ft-h2o
3	Elbow up to Manifold in Vault	2.00 inches	1.860 inches	42.0 gpm	4.96 fps	4.620E+04	0.0216	40	0.33 ft-h2o	40.2 ft-h2o
3	Minimum straight pipe up to manifold 15 pipe Diameters	2.00 inches	1.860 inches	42.0 gpm	4.96 fps	4.620E+04	0.0216	2.5	0.13 ft-h2o	40.3 ft-h2o
3	Weldolet connection assume losses = to Tee connection	2.00 inches	1.860 inches	42.0 gpm	4.96 fps	4.620E+04	0.0216	60	0.50 ft-h2o	40.8 ft-h2o
3	Manifold with in vault assumed length.	8.00 inches	6.830 inches	924 gpm	8.09 fps	2.768E+05	0.0150	14	0.37 ft-h2o	41.2 ft-h2o
3 to 4	Straight piping from vault to Building	8.00 inches	6.830 inches	924 gpm	8.09 fps	2.768E+05	0.0150	259	6.93 ft-h2o	48.1 ft-h2o
4	8" Butterfly Valve	8.00 inches	6.830 inches	924 gpm	8.09 fps	2.768E+05	0.0150	3136	0.20 ft-h2o	48.3 ft-h2o
4	Assume 2 Elbows to well Bypass	8.00 inches	6.830 inches	924 gpm	8.09 fps	2.768E+05	0.0150	40	1.07 ft-h2o	49.4 ft-h2o
4	Straight piping from vault to Building	8.00 inches	6.830 inches	924 gpm	8.09 fps	2.768E+05	0.0150	16	0.43 ft-h2o	49.8 ft-h2o
4	8" Butterfly Valve	8.00 inches	6.830 inches	924 gpm	8.09 fps	2.768E+05	0.0150	3136	0.20 ft-h2o	50.0 ft-h2o
4 to 3	Straight piping from building	8.00 inches	6.830 inches	924 gpm	8.09 fps	2.768E+05	0.0150	259	6.93 ft-h2o	57.0 ft-h2o
3	Manifold with in vault assumed length.	8.00 inches	6.830 inches	924 gpm	8.09 fps	2.768E+05	0.0150	28	0.75 ft-h2o	57.7 ft-h2o
3	Weldolet connection assume losses = to Tee connection	2.00 inches	1.860 inches	42.0 gpm	4.96 fps	4.620E+04	0.0216	60	0.50 ft-h2o	58.2 ft-h2o
3	Minimum straight pipe down from manifold 15 pipe Diameters	2.00 inches	1.860 inches	42.0 gpm	4.96 fps	4.620E+04	0.0216	2.5	0.13 ft-h2o	58.3 ft-h2o
3	Elbow down from Manifold in Vault	2.00 inches	1.860 inches	42.0 gpm	4.96 fps	4.620E+04	0.0216	40	0.33 ft-h2o	58.7 ft-h2o
3	Assumed straight pipe leaving Vault	2.00 inches	1.860 inches	42.0 gpm	4.96 fps	4.620E+04	0.0216	6	0.32 ft-h2o	59.0 ft-h2o
3 to 2	Straight pipe from Main vault to 4 well manifold	2.00 inches	1.860 inches	42.0 gpm	4.96 fps	4.620E+04	0.0216	243	12.96 ft-h2o	72.0 ft-h2o
2	4 well manifold assumed length.	2.00 inches	1.860 inches	42.0 gpm	4.96 fps	4.620E+04	0.0216	8	0.43 ft-h2o	72.4 ft-h2o
2	Weldolet connection assume losses = to Tee connection	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	60	0.16 ft-h2o	72.5 ft-h2o
2	Minimum straight pipe up to manifold 15 pipe Diameters	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	1.6	0.04 ft-h2o	72.6 ft-h2o
2	Assumed straight pipe leaving well manifold	1.25 inches	1.313 inches	10.5 gpm	2.49 fps	1.636E+04	0.0275	6	0.15 ft-h2o	72.7 ft-h2o
	Subtotal									72.7 ft-h2o

Notes:

1. K' from table chapter of Handbook of PE Pipe".
2. Value obtained from Chapter Table of " Handbook of PE Pipe".
3. ID obtained from MFG 'etter "RE: Flow in HDPE Piping".

WELL FIELD MAX PIPE ID LOOP HEAD LOSSES

PROJECT	**Geothermal Pump Peer Review**	DATE
PIPE TYPE	High Density Polyethylene Piping SDR11. See Note 3	
FLUID KINEMATIC VISCOSITY	1.664E-05 ft2/sec based on water temperature of 40°F and a Specific Gravity of 1.	
PIPE ABSOLUTE ROUGHNESS	0.000005 feet: See Note 2	
TOTAL SYSTEM FLOW BASED ON 11 HEAT PUMPS IN OPERATION	924.0 gpm	
INDIVIDUAL WELL FLOW BASED ON 88 WELLS @ EQUAL FLOW	10.5 gpm	

NODES	DESCRIPTION	NOMINAL SIZE	INSIDE DIAMETER	FLOW	VELOCITY	REYNOLDS NUMBER	FRICTION FACTOR	See Note 1 LENGTH OR K' factor	Darcy-Weisbach SECTION LOSS	CUMULATIVE LOSS
2 to 1	From 4 well manifold to top of well	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	40	0.80 ft-h2o	0.8 ft-h2o
1	Elbow down into the well	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	40	0.09 ft-h2o	0.9 ft-h2o
1	Straight pipe to bottom of well	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	500	10.05 ft-h2o	10.9 ft-h2o
1	Elbow to riser at bottom of well	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	40	0.09 ft-h2o	11.0 ft-h2o
1	Elbow at Bottom of riser up out of well	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	40	0.09 ft-h2o	11.1 ft-h2o
1	Straight pipe to top of well	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	500	10.05 ft-h2o	21.2 ft-h2o
1	Elbow at top of well	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	40	0.09 ft-h2o	21.3 ft-h2o
1 to 2	From top of well to 4 well manifold	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	40	0.80 ft-h2o	22.1 ft-h2o
2	Assumed straight pipe entering 4 well manifold	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	6	0.12 ft-h2o	22.2 ft-h2o
2	Elbow up to 4 well manifold	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	40	0.09 ft-h2o	22.3 ft-h2o
2	Minimum straight pipe up to manifold 15 pipe Diameters	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	1.6	0.03 ft-h2o	22.3 ft-h2o
2	Weldolet connection assume losses = to Tee connection	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	60	0.14 ft-h2o	22.4 ft-h2o
2	4 well manifold assumed length.	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	8	0.34 ft-h2o	22.8 ft-h2o
2 to 3	Straight Piping from 4 well manifold vault	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	243	10.24 ft-h2o	33.0 ft-h2o
3	Assumed straight pipe entering Vault	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	6	0.25 ft-h2o	33.3 ft-h2o
3	Elbow up to Manifold in Vault	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	40	0.27 ft-h2o	33.6 ft-h2o
3	Minimum straight pipe up to manifold	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	4	0.17 ft-h2o	33.7 ft-h2o
3	Weldolet connection assume losses = to Tee connection	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	60	0.41 ft-h2o	34.1 ft-h2o
3	Manifold with in vault assumed length.	8.00 inches	7.096 inches	924 gpm	7.50 fps	2.664E+05	0.0149	14	0.31 ft-h2o	34.4 ft-h2o
3 to 4	Straight piping from vault to Building	8.00 inches	7.096 inches	924 gpm	7.50 fps	2.664E+05	0.0149	259	5.69 ft-h2o	40.1 ft-h2o
4	8" Butterfly Valve	8.00 inches	7.096 inches	924 gpm	7.50 fps	2.664E+05	0.0149	3136	0.20 ft-h2o	40.3 ft-h2o
4	Assume 2 Elbows to well Bypass	8.00 inches	7.096 inches	924 gpm	7.50 fps	2.664E+05	0.0149	40	0.88 ft-h2o	41.2 ft-h2o
4	Straight piping from vault to Building	8.00 inches	7.096 inches	924 gpm	7.50 fps	2.664E+05	0.0149	16	0.35 ft-h2o	41.6 ft-h2o
4	8" Butterfly Valve	8.00 inches	7.096 inches	924.0 gpm	7.50 fps	2.664E+05	0.0149	3136	0.20 ft-h2o	41.8 ft-h2o
4 to 3	Straight piping from building	8.00 inches	7.096 inches	924 gpm	7.50 fps	2.664E+05	0.0149	259	5.69 ft-h2o	47.5 ft-h2o
3	Manifold with in vault assumed length.	8.00 inches	7.096 inches	924 gpm	7.50 fps	2.664E+05	0.0149	28	0.62 ft-h2o	48.1 ft-h2o
3	Minimum straight pipe down from manifold 15 pipe Diameters	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	60	0.41 ft-h2o	48.5 ft-h2o
3	Weldolet connection assume losses = to Tee connection	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	2.5	0.11 ft-h2o	48.6 ft-h2o
3	Elbow down from to Manifold in Vault	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	40	0.27 ft-h2o	48.9 ft-h2o
3	Assumed straight pipe leaving Vault	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	6	0.25 ft-h2o	49.1 ft-h2o
3 to 2	Straight pipe from Main vault to 4 well manifold	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	243	10.24 ft-h2o	59.4 ft-h2o
2	4 well manifold assumed length.	2.00 inches	1.949 inches	42.0 gpm	4.52 fps	4.409E+04	0.0216	8	0.34 ft-h2o	59.7 ft-h2o
2	Weldolet connection assume losses = to Tee connection	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	60	0.14 ft-h2o	59.8 ft-h2o
2	Minimum straight pipe up to manifold 15 pipe Diameters	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	1.6	0.03 ft-h2o	59.9 ft-h2o
2	Assumed straight pipe leaving 4 well manifold	1.25 inches	1.363 inches	10.5 gpm	2.31 fps	1.576E+04	0.0275	6	0.12 ft-h2o	60.0 ft-h2o
	Subtotal									60.0 ft-h2o

Notes:

1. K' from table chapter of " Handbook of PE Pipe".
2. Value obtained from Chapter Table of " Handbook of PE Pipe".
3. ID obtained from MFG 'etter "RE: Flow in HDPE Piping".

BUILDING LOOP HEAD LOSSES

PROJECT	Geothermal Pump Peer Review	DATE
PIPE TYPE	Schedule 80 Steel Pipe. See Note 4	
FLUID KINEMATIC VISCOSITY	1.66E-05 ft2/sec based on water temperature of 40°F and a Specific Gravity of 1.	
PIPE ABSOLUTE ROUGHNESS	0.00013 feet: See Note 2	
TOTAL SYSTEM FLOW BASED ON 11 HEAT PUMPS IN OPERATION	924.0 gpm	

NODES	DESCRIPTION	NOMINAL SIZE	INSIDE DIAMETER	FLOW	VELOCITY	REYNOLDS NUMBER	FRICTION FACTOR	See Note 1 LENGTH (ft) OR L_E OR Cv	Darcy-Weisbach SECTION LOSS	CUMULATIVE LOSS
4	Elbow up	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	0.3 ft-h2o
4 to 5	Assumed Straight Pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	10	0.17 ft-h2o	0.5 ft-h2o
4 to 5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	0.9 ft-h2o
4 to 5	Isolation Butterfly Valve	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	3136	0.20 ft-h2o	0.7 ft-h2o
4 to 5	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	1.0 ft-h2o
4 to 5	Assumed Straight Pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	4	0.07 ft-h2o	1.0 ft-h2o
5	Elbow up	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	1.4 ft-h2o
5 to 6	Assumed Straight Pipe up based on Building Elevations	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	1.7 ft-h2o
5 to 6	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	2.1 ft-h2o
5 to 6	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	15	0.26 ft-h2o	2.3 ft-h2o
5 to 6	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	2.7 ft-h2o
5 to 6	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	22	0.38 ft-h2o	3.0 ft-h2o
5 to 6	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	3.4 ft-h2o
5 to 6	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	15	0.26 ft-h2o	3.6 ft-h2o
5 to 6	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	4.0 ft-h2o
5 to 6	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	7	0.12 ft-h2o	4.1 ft-h2o
5 to 6	Elbow down	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	4.4 ft-h2o
5 to 6	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	4.8 ft-h2o
5 to 6	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	5.1 ft-h2o
5 to 6	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	27	0.46 ft-h2o	5.6 ft-h2o
5 to 6	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	5.9 ft-h2o
5 to 6	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	7	0.12 ft-h2o	6.1 ft-h2o
5 to 6	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	6.4 ft-h2o
5 to 6	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	5	0.09 ft-h2o	6.5 ft-h2o
6	Three Way Control Valve assumed Cv=1202 for 8"	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	1202	1.37 ft-h2o	7.9 ft-h2o
6 to 7	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	15	0.26 ft-h2o	8.1 ft-h2o
6 to 7	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	8.5 ft-h2o
6 to 7	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	2	0.03 ft-h2o	8.5 ft-h2o
6 to 7	45° Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	10	0.17 ft-h2o	8.7 ft-h2o
6 to 7	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	15	0.26 ft-h2o	8.9 ft-h2o
6 to 7	45° Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	10	0.17 ft-h2o	9.1 ft-h2o
6 to 7	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	2.5	0.04 ft-h2o	9.1 ft-h2o
6 to 7	45° Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	10	0.17 ft-h2o	9.3 ft-h2o
6 to 7	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	2	0.03 ft-h2o	9.3 ft-h2o
6 to 7	Air Separator See Note 3	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167		4.62 ft-h2o	14.0 ft-h2o
6 to 7	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	14.2 ft-h2o
6 to 7	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	5	0.09 ft-h2o	14.3 ft-h2o
7	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	14.6 ft-h2o
7	Isolation Butterfly Valve	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	4.5	0.08 ft-h2o	14.7 ft-h2o
7	Reducer	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	3136	0.20 ft-h2o	14.9 ft-h2o
7	Assumed Straight Pipe down to pump	6.00 inches	5.761 inches	924 gpm	11.37 fps	3.281E+05	0.0166	6	0.42 ft-h2o	15.3 ft-h2o
7	Suction Diffuser	6.00 inches	5.761 inches	924 gpm	11.37 fps	3.281E+05	0.0166	985	2.03 ft-h2o	17.4 ft-h2o
8	Assume Elbow up	6.00 inches	5.761 inches	924 gpm	11.37 fps	3.281E+05	0.0166	20	1.39 ft-h2o	18.7 ft-h2o
8	Assumed Straight Pipe up	6.00 inches	5.761 inches	924 gpm	11.37 fps	3.281E+05	0.0166	8	0.56 ft-h2o	19.3 ft-h2o
8	Triple duty Valve 4.5 Feet of head loss	6.00 inches	5.761 inches	924 gpm	11.37 fps	3.281E+05	0.0166		4.50 ft-h2o	23.8 ft-h2o
8	Reducer	6.00 inches	5.761 inches	924 gpm	11.37 fps	3.281E+05	0.0166	4.5	0.31 ft-h2o	24.1 ft-h2o
8	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	24.5 ft-h2o
8 to 9	Reverse Return	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	22	0.38 ft-h2o	24.8 ft-h2o
8 to 9	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	8	0.14 ft-h2o	25.0 ft-h2o
8 to 9	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	25.2 ft-h2o
8 to 9	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	3.5	0.06 ft-h2o	25.3 ft-h2o
8 to 9	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	25.5 ft-h2o
8 to 9	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	4.5	0.08 ft-h2o	25.6 ft-h2o
8 to 9	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	25.8 ft-h2o
8 to 9	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	4.5	0.08 ft-h2o	25.9 ft-h2o
8 to 9	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	26.2 ft-h2o
8 to 9	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	26.4 ft-h2o
8 to 9	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	5	0.09 ft-h2o	26.5 ft-h2o
8 to 9	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	26.7 ft-h2o
8 to 9	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	27.0 ft-h2o
8 to 9	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	5	0.09 ft-h2o	27.0 ft-h2o
10 to 11	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	2	0.03 ft-h2o	27.1 ft-h2o
10 to 11	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	27.3 ft-h2o
10 to 11	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	27.6 ft-h2o
10 to 11	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	4	0.07 ft-h2o	27.6 ft-h2o
10 to 11	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	27.9 ft-h2o
10 to 11	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	28.1 ft-h2o
10 to 11	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	5	0.09 ft-h2o	28.2 ft-h2o
10 to 11	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	28.4 ft-h2o
10 to 11	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	28.7 ft-h2o
10 to 11	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	4	0.07 ft-h2o	28.7 ft-h2o
10 to 11	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	29.0 ft-h2o
10 to 11	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	29.2 ft-h2o
10 to 11	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	5	0.09 ft-h2o	29.3 ft-h2o
10 to 11	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	29.6 ft-h2o
10 to 11	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	29.8 ft-h2o
10 to 11	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	5	0.09 ft-h2o	29.9 ft-h2o
10 to 11	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	30.2 ft-h2o
10 to 11	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	8	0.14 ft-h2o	30.4 ft-h2o
10 to 11	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	30.7 ft-h2o
10 to 11	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	17	0.29 ft-h2o	31.0 ft-h2o
11	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	31.3 ft-h2o
11	Straight pipe up	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	10	0.17 ft-h2o	31.5 ft-h2o
11	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	31.8 ft-h2o
11	Straight pipe up	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	5	0.09 ft-h2o	31.8 ft-h2o
11 to 5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	32.2 ft-h2o
11 to 5	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	2	0.03 ft-h2o	32.2 ft-h2o
11 to 5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	32.6 ft-h2o
11 to 5	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	3	0.05 ft-h2o	32.6 ft-h2o
11 to 5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	33.0 ft-h2o
11 to 5	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	3	0.05 ft-h2o	33.0 ft-h2o
11 to 5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	33.3 ft-h2o
11 to 5	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	9	0.15 ft-h2o	33.5 ft-h2o
11 to 5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	33.8 ft-h2o
11 to 5	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	23	0.40 ft-h2o	34.2 ft-h2o
11 to 5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	34.6 ft-h2o
11 to 5	Straight pipe up	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	15	0.26 ft-h2o	34.8 ft-h2o
11 to 5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	35.2 ft-h2o
11 to 5	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	7	0.12 ft-h2o	35.3 ft-h2o
11 to 5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	35.7 ft-h2o
11 to 5	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	12	0.21 ft-h2o	35.9 ft-h2o
11 to 5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	36.2 ft-h2o
11 to 5	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	21	0.36 ft-h2o	36.6 ft-h2o
11 to 5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	36.9 ft-h2o
11 to 5	Straight pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	15	0.26 ft-h2o	37.2 ft-h2o
11 to 5	Elbow down	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	37.5 ft-h2o
11 to 5	Straight pipe down	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	30	0.52 ft-h2o	38.0 ft-h2o
5	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	38.4 ft-h2o
5 to 4	Assumed Straight Pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	10	0.17 ft-h2o	38.5 ft-h2o
5 to 4	Run/Run Tee fitting	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	14	0.24 ft-h2o	38.8 ft-h2o
5 to 4	Isolation Butterfly Valve	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	3136	0.20 ft-h2o	39.0 ft-h2o
5 to 4	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	39.3 ft-h2o
5 to 4	Assumed Straight Pipe	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	10	0.17 ft-h2o	39.5 ft-h2o
4	Elbow	8.00 inches	7.625 inches	924 gpm	6.49 fps	2.479E+05	0.0167	20	0.34 ft-h2o	39.8 ft-h2o
	Subtotal									39.8 ft-h2o

Notes:

1. Valve for equivalent length L_E obtained from Chapter 8 of "Handbook of Air Conditioning Heating and Ventilation
2. Value obtained from Chapter Table of Handbook of PE Pipe".
3. Air Separator head loss obtained from TACO MFG data for a 8" air separator with strainer.
4. ID obtained from Chapter of "Handbook of Air Conditioning Heating and Ventilation

HEAT PUMP LOOP HEAD LOSSES

PROJECT — **Geothermal Pump Peer Review** — DATE

PIPE TYPE — Schedule 80 Steel Pipe. See Note 4

FLUID KINEMATIC VISCOSITY — 1.664E-05 ft2/sec based on water temperature of 40°F and a Specific Gravity of 1.

PIPE ABSOLUTE ROUGHNESS — 0.00013 feet: See Note 2

TOTAL SYSTEM FLOW BASED ON 11 HEAT PUMPS IN OPERATION — 924.0 gpm

FLOW RATE PER HEAT PUMP — 84.0 gpm per heat pump

NODES	DESCRIPTION	NOMINAL SIZE	INSIDE DIAMETER	FLOW	VELOCITY	REYNOLDS NUMBER	FRICTION FACTOR	See Note 1 LENGTH (ft) OR L_E OR Cv	Darcy-Weisbach SECTION LOSS	CUMULATIVE LOSS
8	Weldolet assumed equal to Reducing Tee Run/Branch	2.50 inches	2.323 inches	84 gpm	6.36 fps	7.398E+04	0.0218	18	1.27 ft-h2o	1.3 ft-h2o
8 to 9	Butterfly Valve	2.50 inches	2.323 inches	84 gpm	6.36 fps	7.398E+04	0.0218	196	0.42 ft-h2o	1.7 ft-h2o
8 to 9	Y-Strainer from chart @ 0.6 psi	2.50 inches	2.323 inches	84 gpm	6.36 fps	7.398E+04	0.0218		1.39 ft-h2o	3.1 ft-h2o
8 to 9	Elbow	2.50 inches	2.323 inches	84 gpm	6.36 fps	7.398E+04	0.0218	6.3	0.45 ft-h2o	3.5 ft-h2o
8 to 9	Straight pipe	2.50 inches	2.323 inches	84 gpm	6.36 fps	7.398E+04	0.0218	0.5	0.04 ft-h2o	1.7 ft-h2o
8 to 9	Straight pipe	2.50 inches	2.323 inches	84 gpm	6.36 fps	7.398E+04	0.0218	0.5	0.04 ft-h2o	1.8 ft-h2o
8 to 9	Control Valve	2.50 inches	2.323 inches	84 gpm	6.36 fps	7.398E+04	0.0218	63	4.11 ft-h2o	5.9 ft-h2o
8 to 9	Reducer	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	5.3	0.92 ft-h2o	6.8 ft-h2o
8 to 9	Straight pipe	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	10	1.75 ft-h2o	8.5 ft-h2o
8 to 9	Elbow heel tap thermal well	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	5.3	0.92 ft-h2o	9.5 ft-h2o
8 to 9	Straight pipe	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	3	0.52 ft-h2o	10.0 ft-h2o
8 to 9	FDI Ball Valve/Strainer combination	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	55.1	5.37 ft-h2o	15.4 ft-h2o
8 to 9	Corrugated pipe hose assume equal to piping	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	2.27	0.40 ft-h2o	15.8 ft-h2o
8 to 9	Elbow	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	5.3	0.92 ft-h2o	16.7 ft-h2o
8 to 9	Straight pipe	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	0.25	0.04 ft-h2o	16.7 ft-h2o
8 to 9	Head loss through heat pump. See Note 3	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218		14.00 ft-h2o	30.7 ft-h2o
8 to 9	Straight pipe	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	0.25	0.04 ft-h2o	30.8 ft-h2o
8 to 9	Elbow	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	5.3	0.92 ft-h2o	31.7 ft-h2o
8 to 9	Corrugated pipe hose assume equal to piping	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	2.27	0.40 ft-h2o	32.1 ft-h2o
8 to 9	TA balancing Valve	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	38	11.29 ft-h2o	43.4 ft-h2o
8 to 9	Straight pipe	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	3	0.52 ft-h2o	43.9 ft-h2o
8 to 9	Elbow heel tap thermal well	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	5.3	0.92 ft-h2o	44.8 ft-h2o
8 to 9	Straight pipe	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	10	1.75 ft-h2o	46.6 ft-h2o
8 to 9	Straight pipe	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	0.5	0.09 ft-h2o	46.7 ft-h2o
8 to 9	Reducer	2.00 inches	1.939 inches	84 gpm	9.13 fps	8.863E+04	0.0218	5.3	0.92 ft-h2o	47.6 ft-h2o
8 to 9	Butterfly Valve	2.50 inches	2.323 inches	84 gpm	6.36 fps	7.398E+04	0.0218	196	0.42 ft-h2o	48.0 ft-h2o
9	Weldolet assumed equal to Reducing Tee Run/Branch	2.50 inches	2.323 inches	84 gpm	6.36 fps	7.398E+04	0.0218	18	1.27 ft-h2o	49.3 ft-h2o
	Subtotal									49.3 ft-h2o

Notes:

1. Valve for equivalent length obtained from Chapter of "Handbook of Air Conditioning Heating and Ventilation
2. Value obtained from Chapter Table . of Handbook of PE Pipe".
3. Head loss through the heat pump obtained from MFG's calculator at a flow of 84 gpm.
4. ID obtained from Chapter of "Handbook of Air Conditioning Heating and Ventilation