

# Water source heat pump system (VP)

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## Design Envelope application guide

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# DESIGN ENVELOPE APPLICATION GUIDES

**P**erformance improvements are among the top priorities of many building professionals today. Whether you are a developer, design consultant, engineer, contractor, facility manager or owner, chances are that you face increasing demands to not only reduce costs, but also deliver performance improvements. Public awareness on multiple levels - from the individual all the way through to government bodies - has grown to the point that energy conservation, carbon reduction, tenant comfort, and other health and environment-driven practices are key objectives for any prominent, sizeable building project.

To support and sustain this paradigm shift, Armstrong has developed a suite of advanced fluid flow and HVAC offerings that we call 'Design Envelope solutions'. Design Envelope solutions integrating intelligent demand-based control to deliver optimal performance and the lowest possible cost, both at commissioning and throughout their full operating life.

This document is one of our Design Envelope Application Guides, a set of booklets that discuss a broad range of real-world HVAC scenarios. In each scenario the use of Design Envelope technology can result in tremendous improvements in performance of your HVAC installation (compared to standard industry practice) and ultimately your building - technically, financially, and environmentally.

The intent of this Application Guide is to present HVAC System designers with an alternative to standard practices for design layout, configuration, and design calculations and help you leverage the full potential of Armstrong Design Envelope solutions. Each Application Guide addresses a specific system configuration for HVAC or data center applications. The system configurations cover heating and cooling scenarios, including circuit configurations ranging from all constant flow, to full variable flow and variable speed plant configurations. The Application Guides will present piping arrangements, valving requirements, de-coupler configurations, instrumentation locations, control system options, and the associated impact on first cost and life-cycle costs. The full series of application guides is available for download from Armstrong's website at [www.armstrongfluidtechnology.com](http://www.armstrongfluidtechnology.com)

# APPLICATION DIRECTORY

## HVAC

### COOLING

- 9.561 - Water cooled chiller plant (all-variable)
- 9.562 - Water cooled chiller plant (CP/VS)
- 9.563 - Water cooled chiller plant with economizer
- 9.564 - Ground source heat pump system (VP)

### HEATING

- 9.565 - Condensing boiler plant (VP)
- 9.566 - Condensing boiler plant (CP/VS)

**This guide covers: 9.567 - Closed circuit heat pump system (VP)**

### DISTRICT COOLING

- 9.568 - Water cooled central plant (all-variable)
- 9.569 - Water cooled central plant (CP/VS)
- 9.570 - Water cooled central plant (VP/VS)

## DATA CENTRES

### COOLING

- 9.571 - Water cooled chiller plant with economizer (VP)
- 9.572 - Water cooled chiller plant (all-variable)
- 9.573 - Water cooled chiller plant (CP/VS)

VP = Variable primary flow

CP/VS = Constant primary flow / variable secondary flow

VP/VS = Variable primary flow / variable secondary flow

All-variable = All variable chiller plant, variable primary flow, variable secondary flow, variable condenser flow

Closed circuit heat pump system is a water-source heat pump system that provides heating and cooling throughout a building by using water circulating through a closed piping loop (2-pipe system). Each individual heat pump adds or remove heat from the air within each zone as required to meet its unique heating or cooling load. During zone heating, they extract needed heat (thermal energy) from the main water loop. During zone cooling, heat is rejected into the water loop where it can then be shared with all other heat pumps throughout the building. The system includes variable speed pumps, a closed loop evaporative cooling tower and a condensing boiler that will supplement cooling and heating capacities when needed.

Main water loop is maintained between 60°F-95°F. BMS will start main water loop circulating pump, and either cooling tower or boiler in order to maintain the temperature in that range. In shoulder seasons, some suites will be absorbing heat from main water loop (to heat space) while others will be rejecting heat to the main loop (to cool space); therefore main water loop net energy is zero and no need to start boiler or cooling tower. During summer, more zones will be in cooling mode, rejecting heat to main water loop, and thus increasing loop temperature beyond 95°F cooling tower will come on to maintain 95°F. During winter, more zones will be in heating mode, absorbing heat from main water loop, and thus lowering loop temperature beyond 60°F, boiler will come on to maintain 60°F.

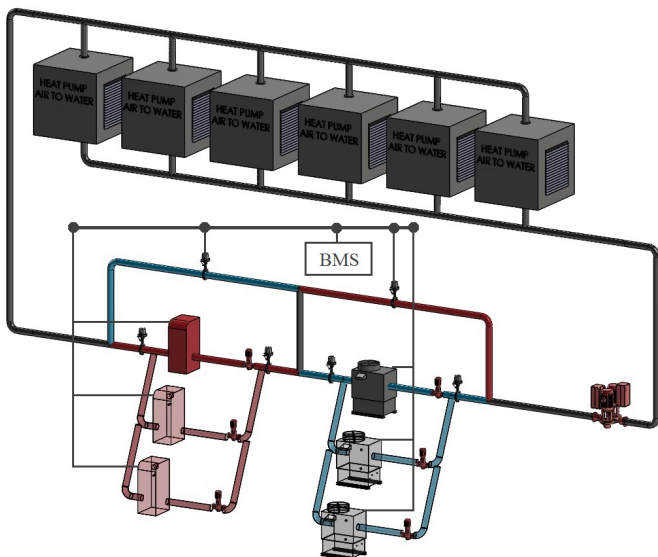
**APPLICATION DETAILS**

Equipment	Air-cooled chillers	1-5
	Heat pumps	•
	Condensing boilers	•
Use	HVAC	•
Configuration	Var. primary flow	•

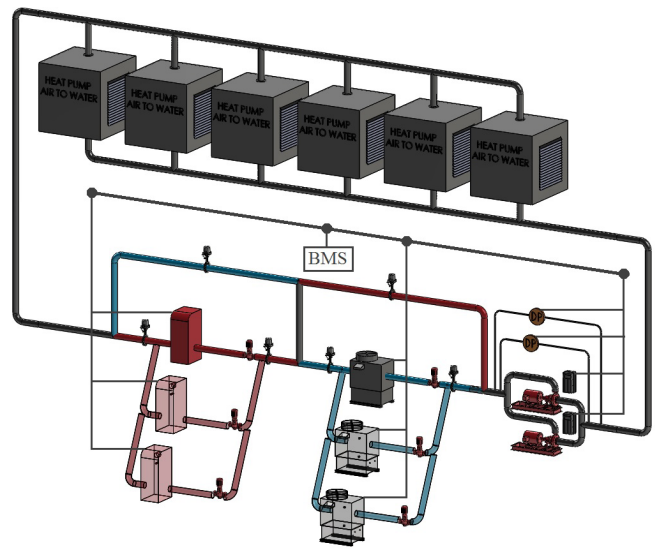
**DESIGN ENVELOPE BENEFITS SUMMARY**

Design Envelope benefit	Design Envelope savings over conventional plant
Lowest installed cost	74%
Lowest operating cost	49%
Lowest environmental cost/impact	Annual reduction in greenhouse gas emissions (tonnes): 59
Lowest project and operating risk	(See table on page 8)
<b>Total Design Envelope 1<sup>st</sup> year savings</b>	<b>66 %</b>

Tremendous benefits at all levels with Armstrong Design Envelope Solutions: consultants [reduced risks for equipment re-selection], contractors [lowest first installed cost] and owners [lowest life cycle cost]. The example presented in this guide shows overall savings of 66% of total installed cost. In Summary, lowest installed cost AND lowest life cycle cost can be now made a reality.



**FIG. 1**  
**DESIGN ENVELOPE PLANT LAYOUT.**



**FIG. 2**  
**CONVENTIONAL PLANT LAYOUT.**

## PLANT LAYOUT DESIGN ENVELOPE VS. CONVENTIONAL

	Design Envelope plant	Conventional plant
Operation	Design Envelope DualArm Vertical In-Line split coupled pump with integrated variable speed controls	<ul style="list-style-type: none"> <li>▪ Duty + 1-standby horizontal end suction pumps</li> <li>▪ Concrete inertia base</li> <li>▪ Flexible connectors</li> </ul>
Controls	Integrated in Design Envelope pump with parallel sensorless technology	<ul style="list-style-type: none"> <li>▪ Variable Frequency Drives remotely mounted on the wall</li> <li>▪ VFDs installation and wiring to remote pumps and BMS</li> </ul>
Pump alternation	Integrated in Design Envelope pump	<ul style="list-style-type: none"> <li>▪ Controlled by BMS via extra Differential Pressure sensors across pumps</li> </ul>
Additional equipment	<ul style="list-style-type: none"> <li>▪ Suction Guide</li> <li>▪ Flo-Trex Valve</li> </ul>	<ul style="list-style-type: none"> <li>▪ Differential pressure sensors</li> <li>▪ Suction Guides</li> <li>▪ Flo-Trex Valves</li> </ul>

With the Design Envelope (DE) solution, DE pumps are self-controlled using Sensorless technology to adjust pump speed to match system demands, with pump sequencing algorithms to drastically improve system efficiency and save energy. The Building Management System (BMS) does not control the DE pumps, thus saving on wiring from BMS to both DE pumps and DP sensors as well as saving on Input/Outputs required by the BMS. The BMS will also still start/stop the pumps, evaporative cooling towers, boilers, and control bypass valves for summer/winter operation.

Design Envelope pumps provides tremendous benefits at all levels: consultants [reduced risks for equipment re-selection], contractors (lowest first installed cost) and owners (lowest life cycle cost).

The conventional approach for the main water loop pumps is base mounted pumps with concrete inertia bases and flex connectors to isolate the vibrating pumps from building piping.

The pumps operate in a 100% duty/standby configuration, and Variable Frequency Drives remotely mounted on the wall. Note the extra-long wires required for this installation. The Building Management System (BMS) controls all equipment; start/stop evaporative cooling towers, boilers and pumps, control bypass valves for summer/winter operation, and adjust pump speed based on extra DP sensors across pumps (over pumping), with duty/standby alternation.

**CLOSED CIRCUIT HEAT PUMP SYSTEMS  
BASE CASE INSTALLATION**

Residential complex : Charlotte, North Carolina

**Details:**

- Residential, 175 suites
- 87,500 square feet
- 2-pipe piping system
- 350 TR
- Main water loop pump: 700 USgpm @ 120 ft
- 25 HP Motor & Controls [compared to 40 HP for conventional system]
- 2 million Btu/hr condensing boiler
- 2 ton heat pumps in suites with integral pumps
- 2-way auto operation bypass valve
- \$0.15/hr electricity cost during peak hours
- \$0.07/hr electricity cost during off peak hours

The Design Envelope approach for the main water loop pumps is 1 Armstrong DE DualArm with integrated controls using Sensorless control algorithms that adjusts the speed of the operating pumps to match system demands and sequences 1 pump off at partial loads. The pumps are sized at 600 USGPM each with capacity to provide design flow when sequencing on the 2nd pump. The result is smaller motors (25hp vs. 40hp), smaller size controls infrastructure (wiring, conduits, fittings, MCC...), eliminating 2 DP sensors w/ wiring, and much higher efficiency operation using Sensorless technology.

DE pump saves energy operating at higher efficiency levels during part load demands vs. conventional systems operating at higher speeds most of the time to maintain constant DP across the pumps.

Specified redundancy is maintained, discussed in details later in this guide.

**DESIGN ENVELOPE BENEFITS SUMMARY**

Design Envelope benefit	Design Envelope savings over conventional plant
Lowest installed cost	\$26,471
Lowest operating cost	Annual \$8,350
Lowest environmental cost/impact	Annual reduction in greenhouse gas emissions (tonnes): 59
Lowest project and operating risk	(See table on page 8)
<b>Total Design Envelope 1<sup>st</sup> year savings</b>	<b>\$34,821 (66%)</b>

By incorporating Design Envelope pumps we are able to provide a lower carbon footprint, more efficient and more economical first cost solution whilst maintaining flexibility and lower life cycle costs.

With Armstrong Design Envelope solutions, customers will enjoy major savings on all levels: lowest installed and operating costs, lowest environmental impact and lowest project risks. In this example the savings amounts to a staggering **\$34,000 which represents 66% savings over the conventional solution;**

A breakdown of the total savings is explained in detail in the following pages.

**LOWEST INSTALLED COST**

Savings area	Design Envelope plant installed savings
Material & installation	\$7,371
Time (labour)	\$2,250
Power infrastructure	\$8,500
Space	\$4,650
Civil structure	\$2,500
Commissioning & call backs	\$1,200
<b>Total installed savings</b>	<b>\$26,471 (74%)</b>

Through optimized Design Envelope pump selections, we are able to select equipment for the same flow and head duty, but with smaller hp motors where we are able to integrate the control/vfd into the pump.

The table above summarizes the achieved savings for the example installation for the total lowest installed cost. We are converting from horizontal base mounted pumps with the VFDs mounted on an adjacent wall to Armstrong Design Envelope Solution which saves on both first installed cost AND life cycle cost! For comparison purposes the cost of boilers, chillers, and cooling towers are not included in the calculations.

**The benefits of Armstrong Design Envelope pumps:**

- Free up wall space by fully integrating pumps and controls
- Wiring savings (material and labour) between wall-mounted VFDs and pumps
- A smaller sized pump motor for the same design conditions
- Electric infrastructure savings; includes smaller size MCC's (25hp vs. 40hp)
- Elimination of DP sensors, installation and wiring to BMS
- Eliminate the inertia base, concrete, coupling alignment, housekeeping pad, and flexible connections for the conventional pumps
- Design flow can be balanced and verified right on the pump controls as they now function as an integrated flow meter
- Reduction in mechanical floor space, 30 sqft saved or 75% less space required for DE pumps
- Commissioning savings (no dp sensors or VFDs on wall)

**LOWEST OPERATING COST**

Savings area	Design Envelope plant operating savings (annually)
Energy	(77,500 kWh @ \$.1/kWh) \$7,750
Maintenance	(\$75/hour) \$600
<b>Total operating savings</b>	<b>\$8,350 (49%)</b>

Energy savings in this example installation stem from the unique Design Envelope pumping system solution. The savings result from operating the Design Envelope pumps at optimum system efficiency at all times using Sensorless technology (instead of controlling pump speed based on dp sensors across the pumps).

When it comes to maintenance, seal changes on Design Envelope pumps are considerably faster than on conventional base mounted pumps. In addition, Armstrong Design Envelope pumps eliminate the need for shaft alignments – which are necessary after seal changes on base mounted pumps.

**LOWEST ENVIRONMENTAL COST**

Savings area	Design Envelope plant environmental savings
Carbon footprint (energy)	(ton GHG [90% NG, 10% hydro]) 59

Above carbon savings were calculated using the Armstrong carbon footprint calculator. The tool accounts for the actual amount of electricity saved as well as the fuel mix for generation used by the local power utility.

There are also savings in concrete [not shown] and are based on conventional pump infrastructure not needed for Design Envelope pumps, such as inertia bases and housekeeping pads.

**LOWEST PROJECT AND OPERATING RISK**

Risk to	Risk source	Design Envelope plant risk reduction	% of total mechanical project
General contractor	Commissioning delay and payment delay of hold back amounts	\$704	0.20%
Owner (capital projects)	Inevitable design changes by different stakeholders	\$267	0.08%
Owner (operations and maintenance)	Energy and operational savings not achieved	\$8,350	2.34%
Engineer	Reputation deterioration and losing new business	\$2,675	0.75%
Mechanical contractor	Commissioning delay and payment delay of hold back	\$287	0.08%

Reduced project risks were estimated based on avoided labor (when using Design Envelope technology over conventional practices) by contractors and engineers for:

- Concrete foundation, pad and coupling alignment
- More parts introduce more complexity for design, purchasing, and coordination for installation
- Components must be synchronized vs Design Envelope is fully factory tested
- Installing and troubleshooting remote differential pressure sensors,
- Wiring pump motors to their corresponding VFDs, and
- Manually balancing system flow.



**Overall benefits offered by Design Envelope Solutions**

Armstrong Design Envelope Solutions offer these value added benefits:

**Design Engineers:**

- Design Envelope Selection Reduces Risk and Cost
- Reduces risks on Future Changes to the load and requirement
- Savings on re-selections
- Use the Integrated Controls as an energy meter for energy measurement verification
- 'Hydronic Systems shall be Proportionately Balanced in a manner to first minimize throttling losses' - ASHRAE compliance
- All HVAC systems shall be balanced - ASHRAE Compliance
- Calibration

**Contractors:**

- Impeller trim is optimized to the motor power
- Ability for digital flow readout and communication to BMS - Ease while commissioning
- Potential wiring savings —with 30 kW motor and controls, the savings is estimated to be \$340 per pump.
- Design Envelope IVS pump controls include built-in DC line reactors (equivalent to 5% AC line reactors)
- Design Envelope IVS pumping unit controls include RFI filters to ensure compliance to low emission and immunity requirements EN61800-3 to the 1st environment class C1 (EN55011 unrestricted sales class B).
- Wall-mounted drives often do not include these and must be provided as an extra.
- Locating the control with the motor will minimize this problem
- No room on wall for multiple VFDs
- Superior control (eliminate DP sensor)
- Pipe Savings
- Wiring Savings
- Motor Control Savings
- Reduces installation time & cost

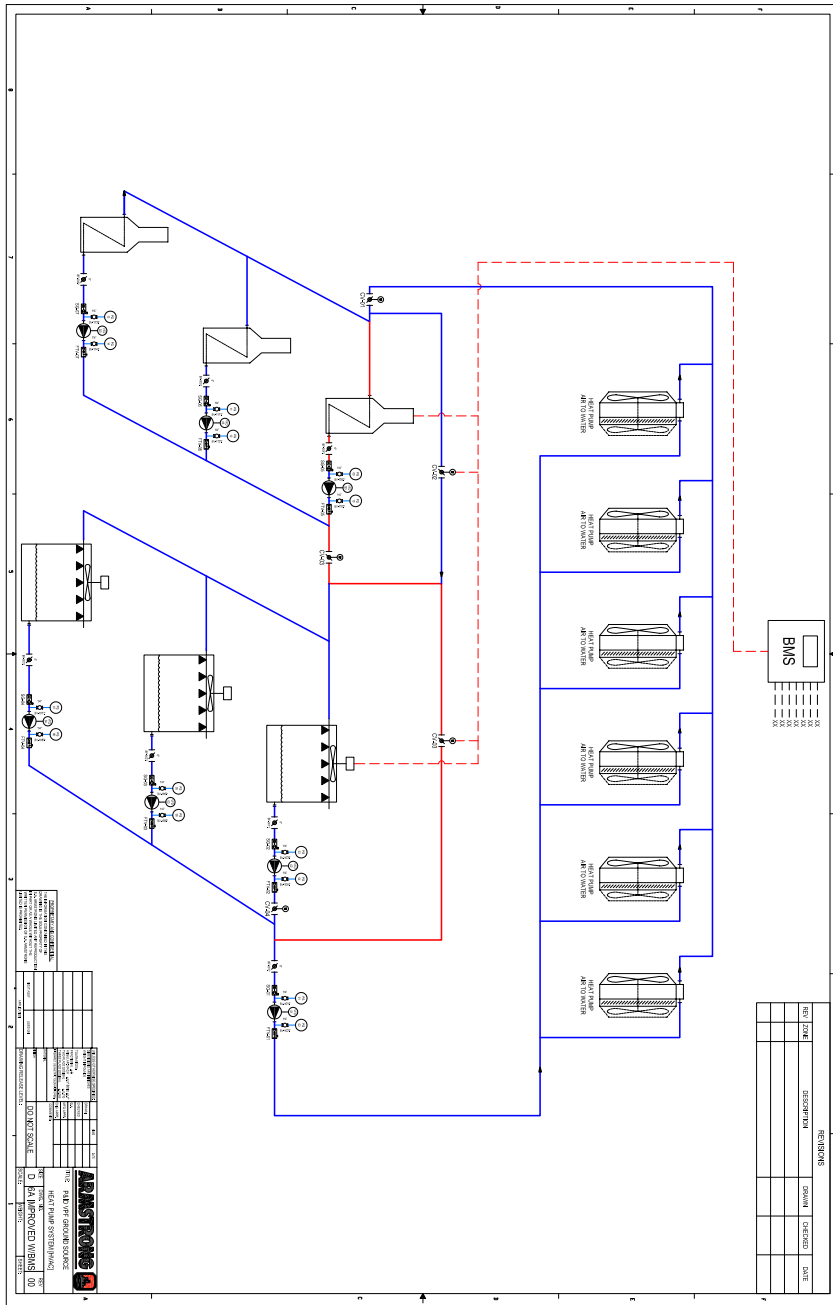
**Owners:**

- Floor Space Savings
- Lowest pump operating costs
- True plug & play - Easy to maintain
- Electronic load limiting
- Design Envelope Pumps advantageous on constant speed applications
- Digital flow readout in all control modes
- Provides a gentle ramp up or down in speed to eliminate the surges, mechanically, electrically, and hydraulically, caused by starting a motor
- Monitors and protects the motor and cables
- Smaller size motor and control
- Reflected wave voltage
- Emission and immunity requirements
- Energy savings of 49% over mechanical room sensor
- Saves Wall space
- First cost savings
- Maintenance Savings

**OTHER CONSIDERATIONS**

- A** For multiple diverse zones or Critical zones where DP sensor across zone is needed - use Armstrong IPS 4000 controller, to control multi zone and multi pumps in parallel using Sensorless technology
- B** If design is specified with 50% redundancy at design (instead of 100%), then use 3 single DE pumps (50/50/50) and control using Parallel Sensorless Technology
- C** This application may also include open cooling towers with heat exchangers in lieu of closed evaporative cooling towers

**PROCESS & INSTRUMENTATION DIAGRAM**



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