

Data Center —

# Water cooled chiller plant (CP/VS)

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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)
- 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)

**This guide covers: 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

This application guide considers a typical chilled water system in a Tier III data center installation. This type of system is a cost effective way of providing cooled water through CRAC (Computer Room Air Conditioning) units that are used to cool the servers within the data center. The need for constant and reliable service delivery from data centers demands a high level of infrastructure availability as defined by the Uptime Institute. Tier III classification requires N+1 redundancy where, in the case of the chilled water system, the plant has duplicated distribution pipework and standby equipment in case of failure. A characteristic of Tier III data centers is that plant items are not required to be concurrently maintainable and as such there will be a shutdown period to enable major equipment maintenance.

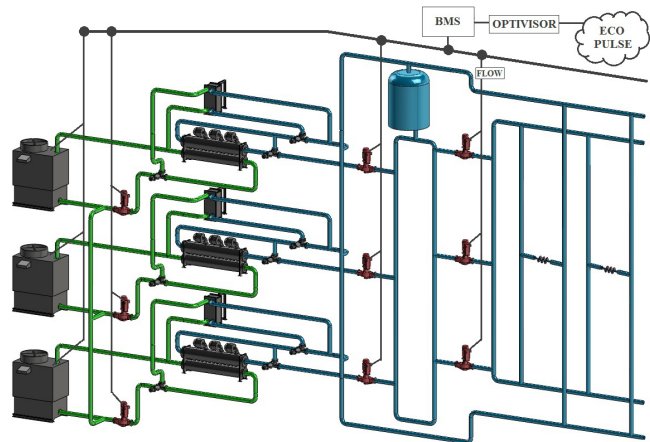
**APPLICATION DETAILS**

Equipment	Water-cooled chillers	1-5
	Economizers	▪
Use	Data center	▪
Configuration	Const. primary flow	▪
	Var. secondary flow	▪
	Const. condenser flow	▪

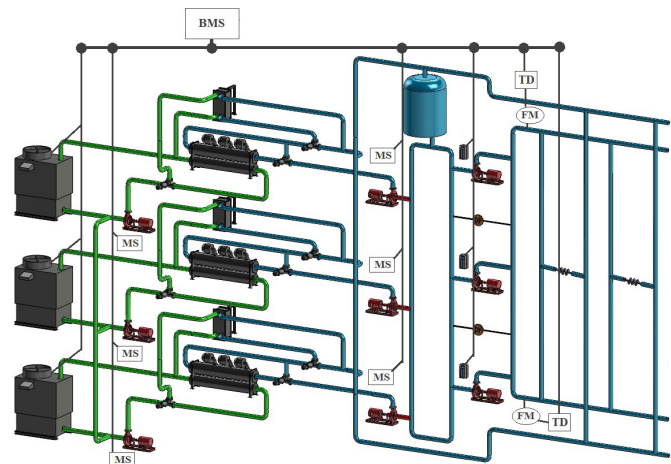
**DESIGN ENVELOPE BENEFITS SUMMARY**

Design Envelope benefit	Design Envelope savings over conventional plant
Lowest installed cost	32%
Lowest operating cost	14%
Lowest environmental cost/impact	Annual reduction in greenhouse gas emissions (tonnes): 690
<b>Total Design Envelope 1<sup>st</sup> year savings</b>	<b>15%</b>

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



**FIG. 2  
CONVENTIONAL PLANT LAYOUT.**  
with base mounted end suction pumps and wall mounted VFD's controlled by BMS on secondary loop



## PLANT LAYOUT DESIGN ENVELOPE VS. CONVENTIONAL

	Design Envelope plant	Conventional plant
Primary loop	Design Envelope 4300 with Suction Guides and Flo-Trex Valves	3 Constant speed chillers with one base mounted end suction pump per chiller
Secondary loop	Design Envelope 4300 with Suction Guides and Flo-Trex Valves	3 Variable speed base mounted end suction pumps
Condenser loop	Design Envelope 4300 with Suction Guides and Flo-Trex Valves	3 Constant speed base mounted end suction pumps

### Design Envelope solution

**FIG. 1** describes a plant layout based on Armstrong Design Envelope Technology.

Primary pumps are Design Envelope 4300 vertical In-line featuring integrated controls with optimized pairing and selection for peak efficiency at part load. They are supplied with Suction Guides and Flo-Trex triple duty valves for reduced installed cost. They are sequenced with the chillers and their speeds recommended by OptiVisor™ to balance the primary and secondary flows while providing the flow required to maintain the storage tank temperature, thus maximizing the delta T and maintaining the minimum flow required by the running chillers. The primary flow can be read from the Design Envelope pumps or from existing flow sensors.

The optimum number of chillers to run is selected by OptiVisor based on heat load. To improve efficiency, the load is distributed among the chillers to maximize the exchange surfaces. When the cooling towers and condenser pumps are dedicated, as in this case, using more chillers than strictly needed allows lower condenser temperatures, even using less fan energy. Combined with variable condenser flow, this substantially reduces the condenser pumping energy. The chilled water supply setpoint is adjusted (if allowed by the loads) also based on heat load, further reducing the required chiller energy use.

Secondary pumps are again Design Envelope 4300 vertical inline fitted with Suction Guides and Flo-Trex valves. The BMS adjusts the speed of the pumps to satisfy the demand measured by zone differential pressure sensors or zones return temperatures. In all speed control modes the optimal number of pumps to run is recommended by OptiVisor using Parallel Sensorless™ control. Each of these pumps alone can supply enough flow to satisfy over 90% of the design heat load, which is in most data centers all that's seen in the first years of operation. The secondary flow can be read from the Design Envelope pumps or the existing flow sensors.

Design Envelope 4300 pumps are sequenced with the chillers and their speed is recommended by OptiVisor based on heat load. Adjusting the condenser flow not only reduces the pumping energy use, but also increases the cooling tower efficiency resulting in lower condenser water temperatures and/or less fans energy use. Tower fans are sequenced with the chillers and their speed recommended by OptiVisor to balance the fans and chillers energy use, further increasing efficiency.

### Conventional solution

A traditional design approach is shown in **FIG. 2** where a mechanical layout comprised of primary, secondary and condenser loops is presented. Additionally, typical BMS (Building Management System) connections are also illustrated.

The cooling plant is based on constant speed compressor type, water cooled chillers. Cooled water on the evaporator side is circulated by constant speed, base mounted end suction, circulating pumps to a low loss header. Each chiller has a dedicated primary pump.

An economizer system is provided, using a plate and frame heat exchanger (one per chiller) with control valves to enable, during cooler periods (generally about 40F, depending on wet bulb), free cooling from the cooling tower to cool the chilled water with the chiller taken out of the circuit and disabled, saving power and reducing running costs.

Secondary cooling base mounted end suction circulating pumps, taking their source from the same header, circulate the water into the data center to cool the servers, through CRACs. The secondary pumps can run at variable speed and their speed is controlled by looking at the difference between the pressure measured by a differential pressure transducer, located at or near to the CRAC and the pressure setting of the set point controller. The Set Point Controller will be programmed with PID software to send an analogue signal to the pump drives to determine the speed. There will be a standby pressure transducer.

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Two port control valves on the CRAC units adjust the volume of chilled water through the units to maintain the determined air temperature in the data hall, with temperature sensors in the data hall sending signal to a temperature set point controller in the CRAC.

On the condenser side of the chillers, condenser water pumps, one per cooling tower, circulate warm water to the cooling towers to reject the heat. They run at constant speed with the cooling tower fans operated at variable speed to maintain a constant chiller entering water temperature.

**PLANT AUTOMATION / CONTROL STRATEGY  
DESIGN ENVELOPE VS. CONVENTIONAL**

Design Envelope plant		Conventional plant	
Primary loop	OptiVisor pump speed and chiller sequencing to maximize delta T	Primary loop- BMS controls and MCC	Pump staging and chiller staging / alternation
Secondary loop	OptiVisor with Parallel Sensorless pump speed and sequencing optimization	Secondary loop- BMS controls	Pump speed / alternation to maintain differential pressure
Condenser loop	OptiVisor pump, chiller and tower sequencing control based on heat load	Condenser loop- BMS controls and MCC	Pump / tower staging with alternation

**WATER COOLED PLANT WITH ECONOMIZER  
BASE CASE INSTALLATION**

Tier III data center: Beijing, China

**Technical details:**

3 chillers @800 ton each (N+1); 3 towers; 3 constant speed condenser pumps, 3 constant primary pumps and 3 variable secondary pumps, with free cooling 3x435 ton HX

**Design conditions:**

- 2400 ton capacity and free cooling, with design ΔT of 9°F
- Tier III data center, 3x800 ton constant speed chillers (N+2) with efficiency of 0.63kW/T
- Heat exchangers 3x435 ton for free cooling
- Primary pump duty 1600 gpm @ 55' per each
- Secondary pump duty 1600 gpm @ 55' per each
- Condenser pump duty 2,400 gpm @ 40' per each
- Outdoor ambient design 75°F wet bulb

**DESIGN ENVELOPE BENEFITS SUMMARY**

Design Envelope benefit	Design Envelope savings over conventional plant
Lowest installed cost	\$38,154
Lowest operating cost	Annual \$136,170
Lowest environmental cost/impact	Annual reduction in greenhouse gas emissions (tonnes): 690
<b>Total Design Envelope 1<sup>st</sup> year savings</b>	<b>\$174.324 (15%)</b>

By incorporating Design Envelope and OptiVisor 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 **\$174,000**; (Note: Total 1<sup>st</sup> year savings (including adder for OptiVisor): \$76,000 or 7%)

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	\$422,43
Additional Controls Cost	\$-98,000
Time (labour)	\$1,050
Power infrastructure	0 hp (0 kW)
Space	\$8,050
Civil structure	\$28,632
Commissioning & call backs	\$450
<b>Total installed savings</b>	<b>\$38,154.43 (32%)*</b>

\*Excluding first cost of OptiVisor

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 every pump from horizontal base mounted constant speed pumps or with the VFDs mounted on an adjacent wall to Armstrong Design Envelope pumps.

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

Improvements offered through the use of Design Envelope technology include:

- Up to 32% lower first installed costs:
  - A** The pumps are suspended from the piping and require no concrete pads, freeing up mechanical room space.
  - B** The integrated VFD's reduce wiring costs. Power is run directly to the pumps and not via a wall mounted vfd. It may be possible to significantly reduce the footprint of the electrical room.
  - C** Installation labour savings are reduced through product integration of pump and vfd.
  - D** Factory integration and programming of Design Envelope pumps reduces on site commissioning costs.
- Up to 14% lower energy costs:
  - E** Design Envelope pumps are designed for best efficiency at part load thereby saving energy for the life of the plant and exceed the requirements set out by ASHRAE 90.1
  - F** Energy savings on the constant flow loops are made possible as the pumps can be commissioned to the system

without throttling.

- G** OptiVisor communicates with the existing Building Management System (BMS) and recommends optimized commands to satisfy the load while minimizing the energy use.
- H** OptiVisor used to balance primary and secondary flows and maximize delta T for optimum energy savings.
- I** To improve efficiency, the load is distributed among the chillers by the OptiVisor to maximize the exchange surfaces.

### LOWEST OPERATING COST

Savings area	Design Envelope plant operating savings (annually)
Energy	(1,000,000 kWh @ \$.13/kWh) \$130,000
Maintenance	(\$75/hour) \$412
Reliability	(increased availability) 20%
Water	(442,938 us gal @ \$0.013/gal) \$5,758
Operator labour	(\$75/hour) N/A
<b>Total operating savings</b>	<b>\$136,170</b>

- A** 0.075 reduction in power usage effectiveness (PUE) is estimated assuming original plant efficiency was 0.8 kW/T improved to 0.45 kW/T and 25% of time in free cooling. Because of the optimization provided from OptiVisor while in mechanical mode and operation of Design Envelope pumps vs. cs.

### REDUCED LIFE CYCLE COSTS (OTHER OPERATING)

- Maintenance savings of more than \$8,200 over the 20 year life span of the pumps are achieved based on quick change mechanical seals
- Reliability is increased by as much as 20% through integration of pump and vfd and onboard filtering, overload protection and short motor cable lengths.
- Reduced evaporation losses in the cooling towers results in water savings of approx. 440,000 gallons per year.

### LOWEST ENVIRONMENTAL COST

Savings area	Design Envelope plant environmental savings	
Carbon footprint (energy)	(ton GHG [90% NG, 10% hydro])	690
Construction waste	(Volume [lbs of material])	2750

### REDUCED ENVIRONMENTAL IMPACT

- J Potential energy savings in this example equate to over 690 tons of greenhouse gas emissions which is comparable to taking 145 cars off the road for a year or generation of electricity for 63 homes.
- K Eliminating concrete bases for pumps and reducing electrical wiring in the installation equates to almost 2750 lbs of site waste reduction.

### 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	\$6,000	0.5%
Owner (capital projects)	Inevitable design changes by different stakeholders	\$10,000	0.8%
Owner (operations and maintenance)	Energy and operational savings not achieved	\$136,000	11.4%
Engineer	Reputation deterioration and losing new business	\$18,000	1.5%
Mechanical contractor	Commissioning delay and payment delay of hold back	\$3,000	0.3%

- L System layout has no single point of failure
- M Reduction of control complexity through leveraging of existing BMS
- N Parallel Sensorless pump control manages equal wear on each pump and ensures redundancy without compromise on energy performance.
- O Sensorless pump control results in differential pressure transducer elimination, plug and play start up, and reduced commissioning time.
- P Quick seal change on 4300 vertical inline pumps reduces any potential downtime for maintenance.

Design Envelope pumping units are designed for non-overloading of tightly sized pumps and motors. Impellers are not selected only for the design conditions, but for the full installed motor capability; thus there is usually inherent safety factors concerning flow and head sizing risk mitigation, as pump speed can be increased within the motor size to produce greater flow or head than design. This increased capability of Design Envelope pumping units, which may even be selected with smaller pump and/or motor to the conventional pump selection, could cause designers to reconsider the need for standby units, as the remaining units may produce sufficient flow for the system, on a break-down; particularly as a vast majority of the time the system requires only partial flow.





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