Water cooled chiller plant (CP/VS)

Design Envelope application guide

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DESIGN ENVELOPE APPLICATION GUIDES

Performance 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

APPLICATION DIRECTORY

HVAC

COOLING

9.561 – Water cooled chiller plant (all-variable)

This guide covers: 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)

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 discusses HVAC chilled water plants with 1-5 chillers, and a constant primary-variable secondary-constant cooling tower chiller plant configuration. It is recommended for chiller plants with cooling loads of 100 tons and greater.

APPLICATION DETAILS

Equipment	Water-cooled chillers	1-5
Use	HVAC	▪
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	39%
Lowest operating cost	6%
Lowest environmental cost/impact	Annual reduction in greenhouse gas emissions (tonnes): 480
Total Design Envelope 1st year savings	**34%**

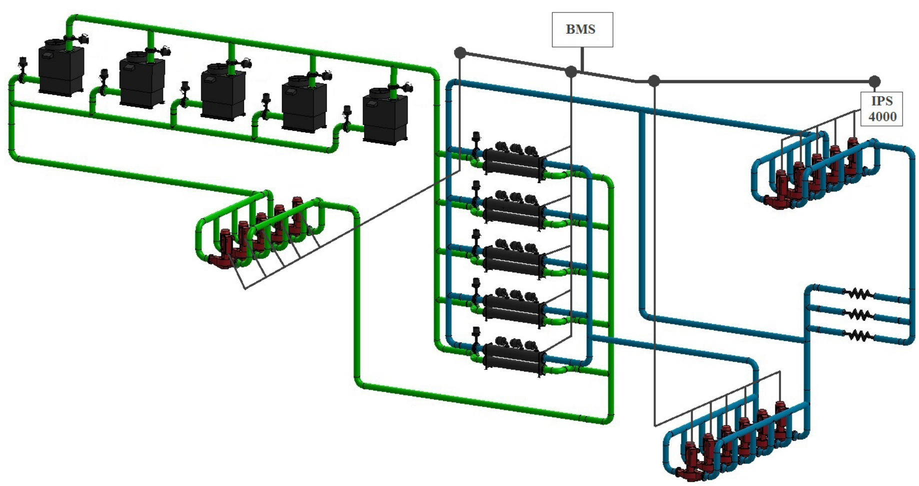


FIG. 1
DESIGN ENVELOPE PLANT LAYOUT.

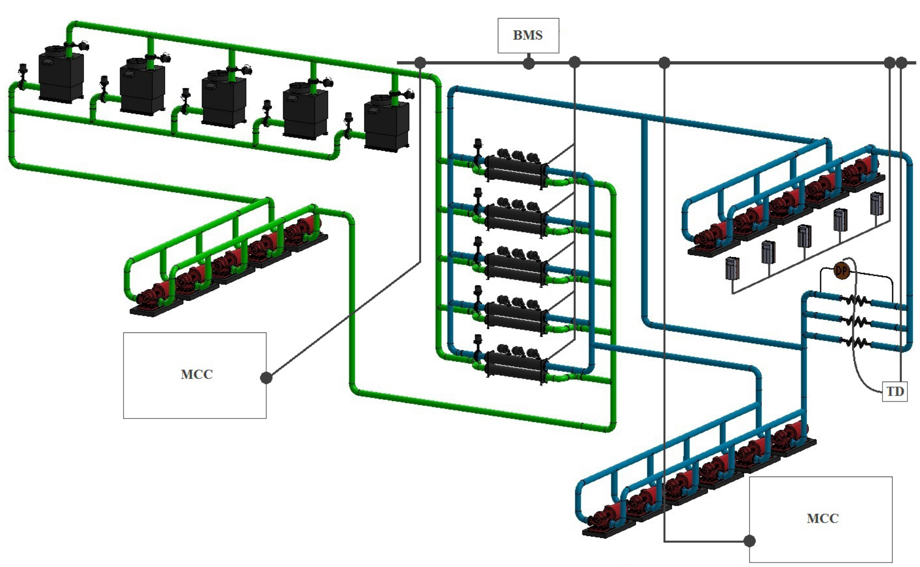


FIG. 2
CONVENTIONAL PLANT LAYOUT.

PLANT LAYOUT
DESIGN ENVELOPE VS. CONVENTIONAL

	Design Envelope plant	Conventional plant
Chiller & control	Constant speed chillers controlled by building automation system (BAS). Typically staged on and off by speed	Constant speed chillers controlled by building automation system (BAS). Typically staged on and off by speed
Primary water pump & control	• Vertical inline Design Envelope pumps with integrated control OR • IPS 4000 pump controller	• Horizontal base-mounted pumps operating constant speed with soft-starts • Separate flow meter to protect chiller from minimum flow
Secondary water pump & control	• Vertical inline Design Envelope pumps with integrated control and Sensorless technology OR • IPS 4000 pump controller OR • Parallel Sensorless Pump Controller (PSPC)	• Horizontal base-mounted variable speed pumps operating with wall-mounted drives • Differential pressure sensors across the building load for each zone
Cooling tower, condenser water pump & control	• Constant speed cooling towers • Vertical inline Design Envelope pumps with integrated control OR • IPS 4000 pump controller	• Horizontal base-mounted pumps operating constant speed. Cooling tower operating in constant speed • Temperature sensor to control condenser water valve and cooling tower staging

A constant primary-variable secondary-constant cooling tower chiller plant configuration typically uses variable speed drives on the secondary pumps only. A building load profile shows that most of its time is spent at part load cooling, well below its design day conditions. Optimized control of the secondary pumps through staging and variable speed operation ensures that the pumps consume only the energy required, based on current system demand. The pumping energy savings can be very attractive to building owners for chilled water plants.

Design Envelope solutions use best-in-class design to provide lowest first cost, lowest life cycle cost, provide redundancy and reliability, and reduce project risk and complexity.

The benefits of the Design Envelope pump arrangement are space savings and low installation costs. The vertical inline pump design typically occupies less than half the footprint of a conventional floor mounted pump.

Ease of maintenance and reliability are also key design features. Vertical split-coupled pumps reduce maintenance headaches. The split-spacer coupling on the 4300 models means that a seal can be serviced without having to move the motor or disturb the pump or piping. Furthermore the VIL pump has only one seal to replace. This gives the vertical pump a significant advantage over base mounted pumps. A horizontal (double suction) split case pump, for example, requires two sets of pump bearings and two sets of seals for a typical service call - the vertical pump only requires one seal. The coupling is also rigid in design so initial site alignment is eliminated and re-attachment of the coupling following maintenance brings the unit back to factory alignment specifications. The vertical nature of the pump provides inherent stability and vibration-free operation. Much as the stability of a spinning top increases with speed, the VIL rotating assembly is specially designed to take advantage of the lack of gravity-induced moments on the shaft to find its natural operating position and run practically vibration free.

Using vertical inline pumps also eliminates the need for concrete pads, inertia bases and flex connections. Furthermore, as less piping and fittings are involved, there are savings in pipe insulation, pipe painting, and reduced complexity.

LARGE CHILLED WATER PLANT BASE CASE INSTALLATION

Miami Florida, USA

Technical details:

- 6250 tons total cooling load
- Design ΔT: 11.7°F (6.5°C)
- Qty 5 chillers + 1 standby, 1250 tons each
- Primary chilled water pumps:
- Max. Flow = 2500 gpm (158 lps)
- Design Head = 65 ft (20m)
- Secondary building loop pump:
- Design Flow = 3125 gpm (197 lps)
- Design Head = 148 ft (45m)
- Condenser water loop
- Design Flow = 3750 gpm (236 l/s)
- Design Head = 92 ft (28 m)
- 2 Way valves

DESIGN ENVELOPE BENEFITS SUMMARY

Design Envelope benefit	Design Envelope savings over conventional plant
Lowest installed cost	$466,600
Lowest operating cost	Annual $118,380
Lowest environmental cost/impact	Annual reduction in greenhouse gas emissions (tonnes): 480
Lowest project and operating risk	(See table on page 8)
Total Design Envelope 1st year savings	**$607,115 (34%)**

By incorporating Design Envelope pumps and controls, a lower carbon footprint, more efficient and more economical first cost solution can be provided whilst also 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 **$607,115**.

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	$218,404
Time (labour)	TBD
Power infrastructure	335 KW
Weight	46,964 KG
Space	$135,600
Utility rebates	$107,800
Commissioning & call backs	$4,800
Total installed savings	**$466,604 (39%)**

Through optimized Design Envelope pump selections, smaller equipment for the same flow and head duty can be selected, and sometimes with a smaller motor power and integrated controls.

The table above summarizes the achieved savings for the example base case for the total lowest installed cost.

In this example, horizontal split case pumps with wall mounted VFDs are compared to Armstrong Design Envelope pumps.

The benefits of Armstrong Design Envelope pumps:

- Free up wall space by integrating the VFD onto the motor
- Wiring savings (material and labour) between VFDs on wall and pumps
- In many selections, a smaller sized pump motor for the same design conditions through Design Envelope load-limiting logic
- Eliminate the inertia base, grouting, concrete housekeeping pad, and flexible connections and coupling re-alignment for the base-mounted pumps
- Design flow can be balanced and verified right on the pump controller as it is now an integrated flow meter
- For secondary pumping, the use of Armstrong's Sensorless pump control can eliminate the need for differential pressure sensors to save more than $2000 in first installed cost
- Reduction in mechanical floor space
- Commissioning savings (no DP sensors or VFDs on wall)

LOWEST OPERATING COST

Savings area	Design Envelope plant operating savings (annually)	
Energy	(1,078,000 KWH @$.1/KWH)	$107,800
Maintenance	($75/hour)	$10,577
Reliability	(increased availability)	16.66%
Water		TBD
Operator labour	($75/hour)	N/A
Total operating savings		**$118,377 (6%)**

Chiller and control: Constant speed chillers in parallel are controlled by building automation system (BAS). Typically staged on and off by speed. As the cooling load increases or more cooling is required, more chillers are staged on to meet the building's demand. As the load decreases, chillers can be staged off to save energy.

A more efficient way of managing the control of the chillers is to stage them by power demand. The demand based control concept involves staging multiple chillers and operating them at part load so that each chiller runs at highly efficient conditions instead of running fewer chillers at inefficient conditions. This ultimately lowers the overall power consumption of the plant and achieves 25-30% energy savings over conventional speed control.

Primary water pump and control: When the chillers operate in constant speed mode, the primary water pumps operate in constant speed also. To balance the system, it is recommended that throttling losses be minimized and pump impellers be trimmed to meet design flow conditions – this is rarely done in practice.

Design Envelope pumps operate at reduced speed to allow you to save 15% in energy compared to operating at full speed or throttling to match the design flow. As VFDs have become more economical, many designers are specifying them as “soft” starters for primary pumps; Design Envelope pumps are equipped with integrated controls that can slowly ramp up speed to protect your equipment from hydraulic, mechanical, and electrical surges.

Secondary water pump and control: While a building's HVAC system is designed for peak-day requirements, they operate at part-load the vast majority of the time. Secondary pumps which serve the building loads, are the greatest opportunity for pump energy savings. In a hydraulic system, flow rate is proportional to speed - and power is proportional to the cube of the speed. So small changes in pump speed result in huge savings to energy consumption. The ASHRAE 90.1 standard requires that secondary pumps (greater than 5hp) save 70% energy at 50% system load.

Design Envelope Pumps: At partial loads, control valves in the secondary loop are throttled to limit the flow across the cooling coils. In turn, the secondary water pumps react to change in differential pressure of the system by slowing down in speed. Rather than using a differential pressure (DP) sensor, Design Envelope pumps use Sensorless control technology to vary the speed of the secondary pumps. Sensorless control emulates the performance of a single zone DP sensor through an algorithm embedded in the integrated control – eliminating installation cost and potential problems such as sensor location, maintenance, and wiring. Commissioning is also simplified as the pumping unit with integrated control is factory pre-wired and pre-programmed by Armstrong.

Parallel Sensorless Pump Controller: For single zone systems with up to 4 pumps operating in parallel, the Parallel Sensorless Pump Controller (PSPC) combines the advantages of variable speed technology and parallel pumping. Pumps are staged for optimal energy efficiency and sequenced for even distribution of operating hours. The controller can be wired to that pump with the other units ‘daisy-chain’ control wired on site, by the controls contractor. Using Sensorless technology, the PSPC eliminates the added costs and complexity of installing a DP sensor.

IPS 4000: For applications with up to 12 zones and up to 6 pumps operating in parallel, the IPS 4000 controller can be used to coordinate pump operation. For installations with new or existing BAS systems, the IPS is capable of full serial communications for easy integration. The IPS 4000 can use zone DP sensors or Sensorless technology to control the pumps for energy efficient operation.

iFMS: Armstrong's Intelligent Fluid Management System (iFMS) is a pre-fabricated all-variable speed pumping system. It has all the advantages of Armstrong Design Envelope solutions in an integrated approach offered with various level of control either through the BAS system or through onboard control using Sensorless technology, multiple zone and pumping controls with the IPS 4000 controller. By integrating the controls into a pre-fabricated pump station, the solution is factory tuned for on-board equipment ensuring that there are no commissioning complications, delays, or future well intended adjustments on site.

Cooling tower, condenser water pump and control: Condenser water pumps are generally the largest size pumps in a chilled water pumping system and represent an untapped area of energy savings. With the cooling tower fans operating in constant speed mode, the condenser water pumps operate in constant speed also. To balance the system, it is recommended that throttling losses be minimized and pump impellers be trimmed to meet design flow conditions – this is rarely done in practice.

Design Envelope Pumps: Design Envelope pumps operate at reduced speed to save 15% in energy compared to operating at full speed or throttling to match the design flow. As VFDs have become more economical, many designers are specifying them as “soft” starters for condenser water pumps; Design Envelope pumps are equipped with integrated controls that can slowly ramp up speed to protect your equipment from hydraulic, mechanical, and electrical surges.

LOWEST ENVIRONMENTAL COST

Savings area	Design Envelope plant environmental savings	
Carbon footprint (energy)	(ton GHG)	480

The carbon footprint calculation is based on Armstrong’s Eco:nomics calculator tool for greenhouse gas emissions reductions. It is based on the kW/hr energy saved as well as the annual electricity fuel mix for the local power utility. The 480 tons of greenhouse gas savings is equivalent to 101 cars off the road annually.

PUMPING SAFETY FACTORS

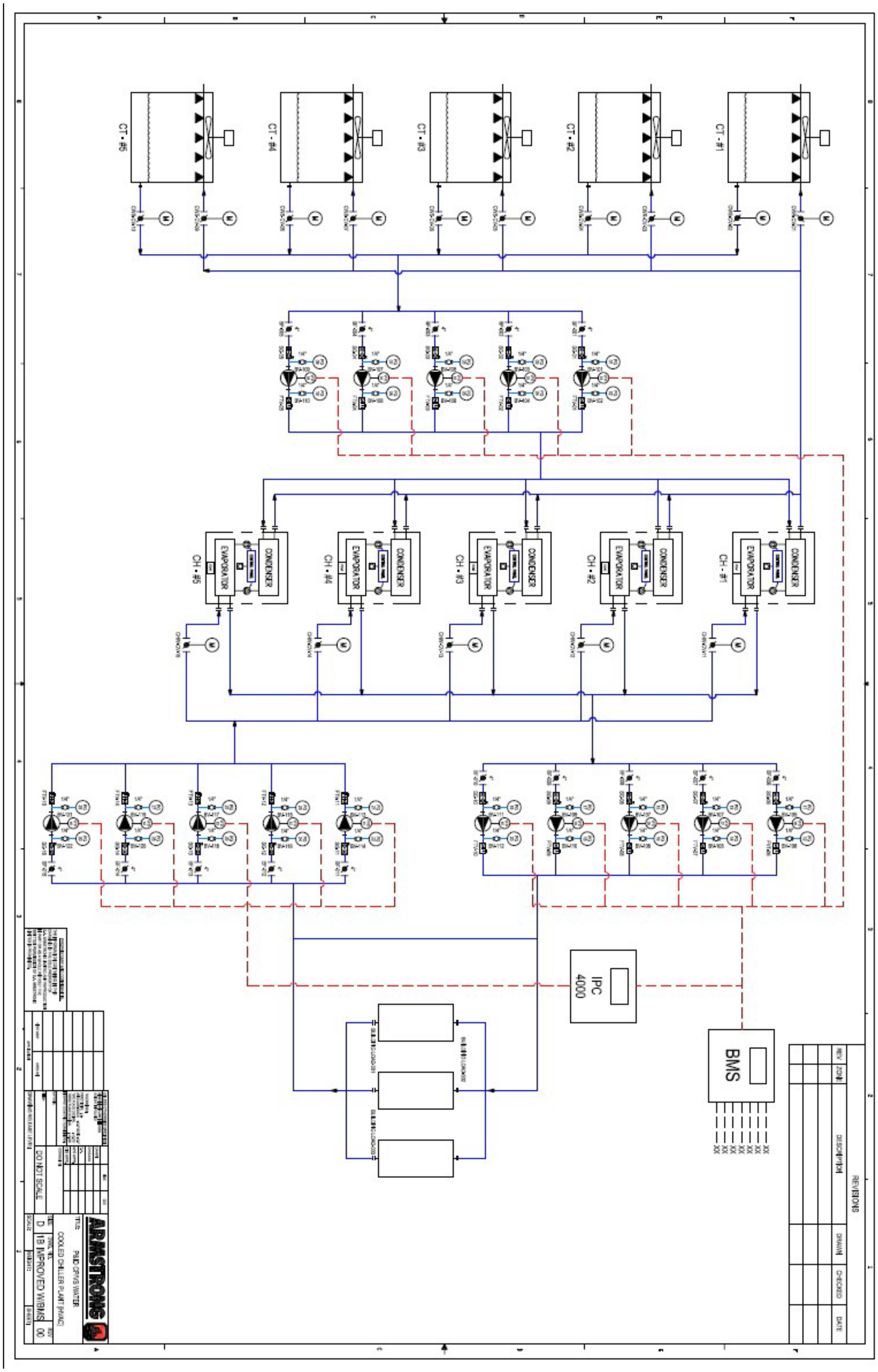
Duty	Measure	Design Envelope improvement over conventional plant	
		EACH PUMP	TOTAL
Primary	Flow @ design head	9%	56%
	Head @ design flow	17%	54%
	Flow @ 50% avg. load	12%	3%
Secondary	Flow @ design head	-58%	-58%
	Head @ design flow	-59%	-59%
	Flow @ 50% avg. load	-19%	-19%
Condenser	Flow @ design head	24%	24%
	Head @ design flow	13%	13%
	Flow @ 50% avg. load	49%	49%

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	$52,201	1.32%
Owner (capital projects)	Inevitable design changes by different stakeholders	$23,113	0.59%
Owner (operations and maintenance)	Energy and operational savings not achieved	$118,376	3.00%
Engineer	Reputation deterioration and losing new business	$59,100	1.50%
Mechanical contractor	Commissioning delay and payment delay of hold back	$11,163	0.28%

The project risk has been approximated on the amount of time that the general contractor and engineer would have to spend on installing and troubleshooting remote differential pressure sensors, co-ordinating the electrical installation of the VFDs to the traditional horizontal pump motors, time spent as risk in balancing the system flow traditionally verses utilizing the Design Envelope pumps to measure and balance the design flow at the pump

PROCESS & INSTRUMENTATION DIAGRAM



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