ARMSTRONG

Data Center

Water cooled chiller plant (all-variable)

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

9.561UK – Water cooled chiller plant (all-variable)

9.562UK – Water cooled chiller plant (CP/VS)

9.563UK – Water cooled chiller plant with economiser

9.564UK – Ground source heat pump system (VP)

HEATING

9.565UK – Condensing boiler plant (VP)

9.566UK – Condensing boiler plant (CP/VS)

9.567UK – Closed circuit heat pump system (VP)

DISTRICT COOLING

9.568UK – Water cooled central plant (all-variable)

9.569UK – Water cooled central plant (CP/VS)

9.570UK – Water cooled central plant (VP/VS)

DATA CENTRES

COOLING

9.571UK – Water cooled chiller plant with economiser (VP)

This guide covers: 9.572UK – Water cooled chiller plant (all-variable)

9.573UK – 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 II 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 II classification requires N+1 redundancy where, in the case of the chilled water system, each plant item has standby equipment in case of failure. A characteristic of Tier II data centers is that plant items are not required to be concurrently maintainable and as such there will be a shutdown period for equipment maintenance.

APPLICATION DETAILS

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

DESIGN ENVELOPE BENEFITS SUMMARY

Design Envelope benefit	Design Envelope savings in example installation over conventional plant ($)
Lowest installed cost	57%
Lowest operating cost	21%
Lowest environmental cost/impact	Annual reduction in greenhouse gas emissions (tonnes): 408
Lowest project and operating risk	(See table on page 8)
Total Design Envelope 1st year savings	**33 %**

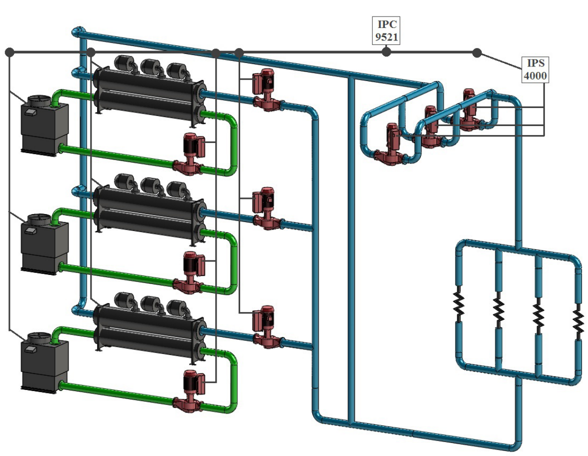


FIG. 1
DESIGN ENVELOPE PLANT LAYOUT.

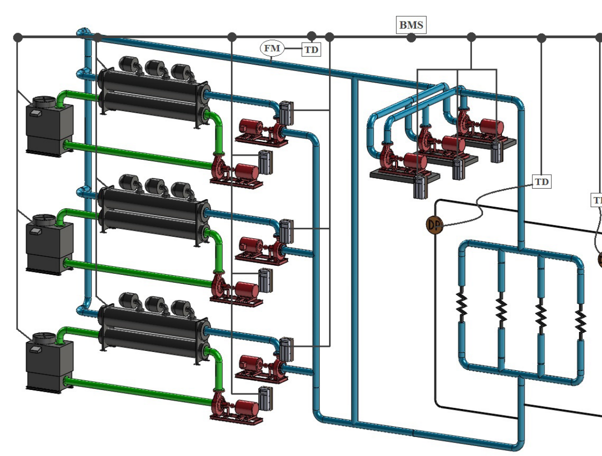


FIG. 2
CONVENTIONAL PLANT LAYOUT

PLANT LAYOUT
DESIGN ENVELOPE VS. CONVENTIONAL

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

Design Envelope Solution

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

Primary pumps are Design Envelope 4300 vertical in-line featuring integrated controls with optimised pairing and selection for peak efficiency at part load. The pumps are fitted with Suction Guides and Flo-Trex valves and are designed to be pipeline mounted, thereby reducing installed costs and reducing installed space requirements.

An IPC9521 water cooled chiller plant controller manages these pumps, the chillers, the condenser pumps and the cooling towers. The controller sequences the pumps with the chillers and adjusts their speed to match the primary and secondary flows, thus maximising the delta T, while maintaining the minimum flow through the running chillers. The primary flow can be read from the Design Envelope pumps or from a flow sensor.

Chillers are sequenced based on heat load and their supply setpoint is adjusted based on heat load, by the IPC9521 . To improve efficiency, the load is distributed among the chillers to maximise the exchange surfaces. When the cooling towers and pumps are dedicated, as in this case, using more chillers than strictly needed allows achieving lower condenser temperatures, even using less fan energy. And combined with variable condenser flow, this substantially reduces the condenser pumping energy.

Secondary pumps are again Design Envelope 4300 vertical inline fitted with Suction Guides and Flo-Trex valves. An IPS4001 controller adjusts the speed of the pumps to satisfy the demand measured by zone differential pressure sensors, zones return temperatures or Armstrong's patented Parallel Sensorless™.
In all speed control modes the pumps are optimally sequenced using Parallel Sensorless™ ensuring the most efficient configuration is used at all times. 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. This provides significant redundancy at most loads.

Design Envelope 4300 pumps are sequenced with the chillers and their speed is controlled based on heat load by the IPC9521 . 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 controlled based on heat load by the IPC9521 . This balances the fans and chillers energy use, further increasing efficiency.

Conventional Solution

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

Base mounted pumps with wall mounted variable drives are controlled by the BMS to deliver sufficient flow through the chillers based on cooling demand. Each chiller has a dedicated pump and the system is sized such that one pump and chiller is always available as standby should a chiller / pump pair fail.

Base mounted end suction circulating pumps take their source from a common header and deliver the required cooling water to CRAC units in the data center. The pumps are variable speed controlled from wall mounted VFD's connected to the BMS.
A duty / standby differential pressure sensor arrangement is located across a remote load and its two port control valve and the pressure setting for the circuit design flow resistance is programmed into the BMS such that pump speed will be controlled based on pressure changes caused by demand fluctuation in the data center.

The three pumps in the secondary loop are sized such that there is always a standby and are operated in parallel by the BMS such that in periods of high demand, all pumps will be running (at the same speed). The staging principle employed is typically based on pre-determined stage on and off speeds for each pump (i.e. 90% on, 55% off) however this can lead to wasted energy when compared to best efficiency staging principles (where a 32% saving is typical).

On the condenser side of the chillers, condenser water pumps, one per cooling tower, circulate warm water to the cooling towers to reject heat. The pumps and cooling tower fans operate on variable speed to maintain constant chiller entering water temperature.

PLANT AUTOMATION / CONTROL STRATEGY DESIGN ENVELOPE VS. CONVENTIONAL

Design Envelope plant		Conventional plant	
Primary loop	IPC9521 pump and chiller speed control and sequencing to maximise delta T	BMS controls	• Pump speed and chiller speed control / alternation
Secondary loop	IPS4001 with Parallel Sensorless pump speed and sequencing optimisation	BMS controls	• Pump speed / alternation to maintain differential pressure
Condenser loop	IPC9521 pump, chiller and tower sequencing control based on heat load	BMS controls	• Pump / tower speed control for constant water temp with alternation

WATER COOLED CHILLER PLANT BASE CASE INSTALLATION

Tier II data center: Sao Paulo, Brazil

Technical details:

2110 kW load; 3 chillers @1055 kW each; 3 towers; 3 variable condenser pumps, 3 variable primary pumps and 3 variable secondary pumps, with 50% redundancy at design and average load, no by-pass with 2 way valves.

Design conditions (50% redundancy):

- 2110 kW plant load, with design △T of 6.6°c
- Tier II data center, 3x1,055 kW variable speed chillers with efficiency of COP 5.6
- Primary pump flow 136 m^3/h @ 17 m per each
- Secondary pump flow 136 m^3/h @ 15 m per each
- Condenser pump flow 241 m^3/h @ 18 m per each
- Outdoor ambient design 24°c wet bulb

DESIGN ENVELOPE BENEFITS SUMMARY

Design Envelope benefit	Design Envelope savings over conventional plant
Lowest installed cost	£54250
Lowest operating cost	Annual £41142
Lowest environmental cost/impact	Annual reduction in greenhouse gas emissions (tonnes): 408
Lowest project and operating risk	(See table on page 8)
Application requirement fulfillment	-
Total Design Envelope 1st year savings	**£95392 (33%)**

By incorporating Design Envelope and Integrated Plant Control 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 **£95000**;

These savings result from BMS replacement with IPC and IPS control, simplified piping and space savings and civil structure savings with Design Envelope pumps combined with reduced operating cost (the cost of chillers and cooling towers are excluded).

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

LOWEST INSTALLED COST

Savings area	Design Envelope plant installed savings
Material & installation	£40722
Time (labour)	£2068
Power infrastructure	9kW (12 hp)
Space	£5415
Civil structure	£5159
Commissioning & call backs	£886
Total installed savings	**£54250 (57%)**

Through optimised 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 summarises the achieved savings for the example installation for the total lowest installed cost.

We are converting every pump from horizontal base mounted pumps with the VFDs mounted on an adjacent wall to Armstrong Design Envelope pumps.

With space savings and civil structure savings total installed savings over conventional approach are 57% of the plant cost excluding chillers and cooling towers.

The benefits of Armstrong Design Envelope pumps:

- Up to 57% 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** BMS complexity is significantly reduced and a large number of I/O points can be removed through the use of the IPC9521 and IPS4000.
  - **D** Parallel Sensorless pump control removes the need for remote DP sensors.
  - **E** Installation labour savings are reduced through product integration of pump and VFD.
  - **F** Factory integration, programming and Sensorless capability of Design Envelope pumps reduces on site commissioning costs.
  - **G** For the secondary loop, selecting DE 4300 pumps reduces the kW requirement per pump from 11 kW to 7.5 kW and thereby reducing electrical infrastructure costs.
- More than 20% lower energy costs:
  - **H** 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
  - **I** IPC9521 distributes the load among the chillers to maximise the exchange surfaces, thereby improving efficiency.
  - **J** IPC9521 adjusts condenser pump speed based on chiller heat load which reduces pump energy and increases cooling tower efficiency.
  - **K** Tower fans are sequenced with the chillers and their speed controlled based on heat load by the IPC952. This balances the fans and chillers energy use, further increasing efficiency.
  - **L** Parallel Sensorless pump control utilises best efficiency staging which can save 32% energy when compared to BMS speed staging
  - **M** Removing the need for remote DP sensors also removes the risk that were incorrectly situated for best energy savings. Sensorless control allows optimisation of system performance based on both operation and energy consumption.

LOWEST OPERATING COST

Savings area	Design Envelope plant operating savings (annually)	
Energy		£38813
Maintenance	(£50/hour)	£203
Reliability	(increased availability)	10%
Water	(943,142 L @ £0.002/L)	£2126
Operator labour	(£50/hour)	N/A
Total operating savings		**£41142 (21%)**

It is estimated that a 0.1 reduction in power usage effectiveness (PUE) is possible assuming original plant efficiency was 3.52 COP improved to 5.4 COP. afforded by the optimisation provided from IPS and IPC and operation improvement of Design Envelope pumps vs. pumps with drive on the wall.

- Reduced Life Cycle Costs (other Operating)
  - **N** Maintenance savings of more than £3938 over the 20 year life span of the pumps are achieved based on quick change mechanical seals

- o Reliability is increased by as much as 10% through integration of pump and VFD and onboard filtering, overload protection and short motor cable lengths.
- P Reduced evaporation losses in the cooling towers results in water savings of approx. 946 m^3 per year.

LOWEST ENVIRONMENTAL COST

Savings area	Design Envelope plant environmental savings	
Carbon footprint (energy)	(ton GHG [90% NG, 10% hydro])	408
Construction waste	(kg of material)	313

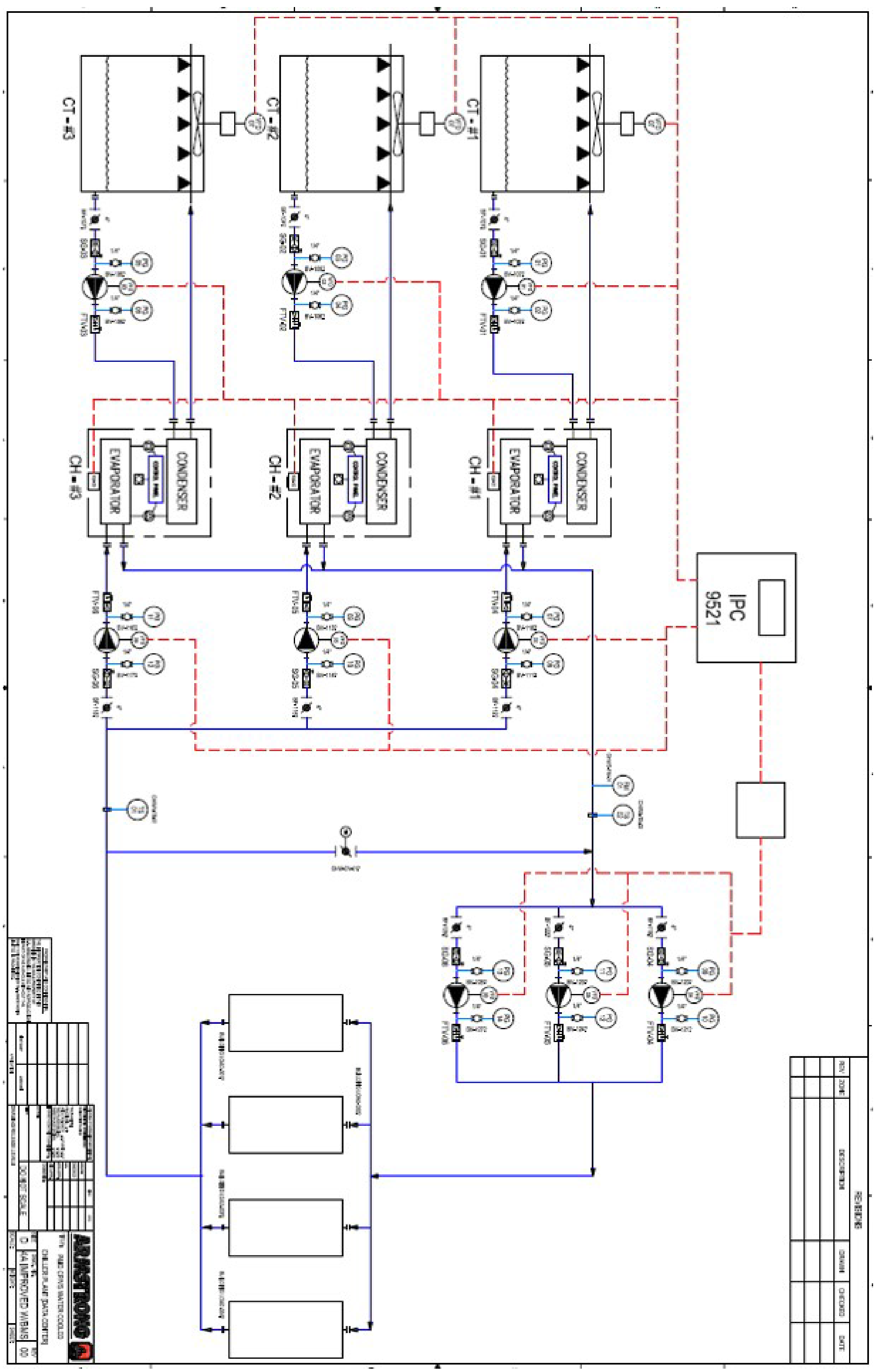
- Reduced Environmental Impact
  - Q Potential energy savings in this example equate to over 400 tons of greenhouse gas emissions which is comparable to taking 86 cars off the road for a year or generation of electricity for 33 homes.
  - R Eliminating concrete bases for pumps and reducing electrical wiring in the installation equates to almost 315 kg of site waste reduction.
- lowest project and operating risk
  - S Meeting construction schedule with minimal on site labour through integrated pumping systems for both primary and secondary loops.
  - T Parallel Sensorless pump control manages equal wear on each pump and ensures redundancy without comprise on energy performance.
  - U Sensorless pump control results in differential pressure transducer elimination, plug and play start up, and reduced commissioning time.
  - V Quick seal change on 4300 vertical inline pumps reduces any potential downtime for maintenance.

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	£40,000	4.2%
Owner (capital projects)	Inevitable design changes by different stakeholders	£16,750	1.5%
Owner (operations and maintenance)	Energy and operational savings not achieved	£41,350	4.3%
Engineer	Reputation deterioration and losing new business	£14,450	1.5%
Mechanical contractor	Commissioning delay and payment delay of hold back	Included in general contractor	

Design Envelope pumping units are designed for non-overloading of tightly sized pumps and motors. Impellers are selected not 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.

PROCESS & INSTRUMENTATION DIAGRAM



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