ARMSTRONG

Data center

Water cooled chiller plant with economiser (VP)

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 – All-variable water cooled chiller plant

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

This guide covers: 9.571UK – Water cooled chiller plant with economiser (VP)

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 analyses a Water Cooled Chiller plant for a Data Centre with the following features:

- Variable primary flow,
- Variable Condenser pumps,
- an Economiser with plate & frame heat exchanger
- a Storage Tank
- Variable speed cooling tower

The paper also examines the effect of the pumps (in terms of sizing) and the controls for the overall plant. With the utilisation of Engineering principles and applying Armstrong Design Envelope solutions, we will further examine the effect of these solutions in terms of first cost, life cycle cost and the effect on the Environment in terms of Co_2 emissions.

An example will be provided for this application within this paper; this should provide the reader with a better understanding of how the selections were completed and why one option was selected over the other.

APPLICATION DETAILS

Equipment	Water-cooled chillers	•
	Economiser	•
Use	Data center	•
Configuration	Var. primary flow	•
	Var. tower flow	•

DESIGN ENVELOPE BENEFITS SUMMARY

Design Envelope benefit	**Design Envelope savings over conventional plant**
Lowest installed cost	29%
Lowest operating cost	23%
Lowest environmental cost/impact	Annual reduction in ghg emissions (tonnes): 182
Lowest project and operating risk	4.5%
Total Design Envelope 1st year savings	**46%**

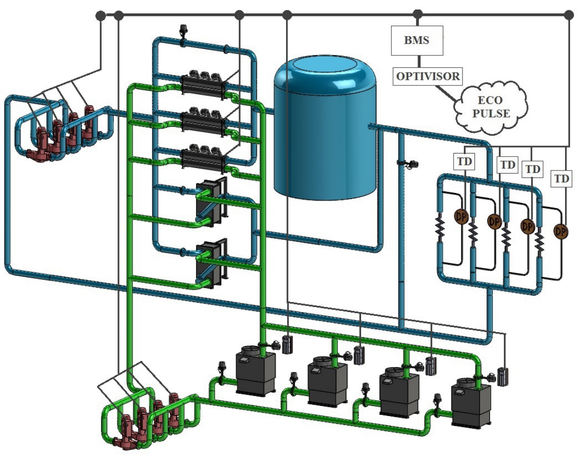


FIG. 1
DESIGN ENVELOPE PLANT LAYOUT.

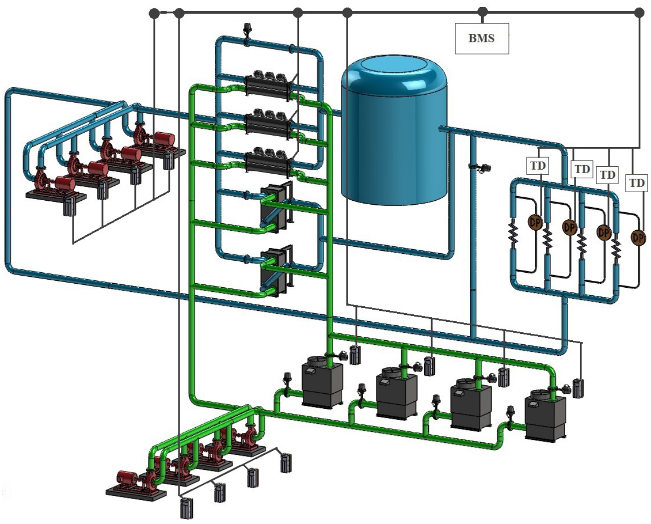


FIG. 2
CONVENTIONAL PLANT LAYOUT.

PLANT LAYOUT
DESIGN ENVELOPE VS. CONVENTIONAL

Design Envelope plant	Conventional plant
Modular approach • Chilled water pumps to be Design Envelope (if redundancy can be secured with 3 pumps) • Condenser water pumps to be Design Envelope (if redundancy can be secured with 3 pumps) • Economiser to be Armstrong Plate and Frame HX • Controls: OPTI-VISOR™	2110 kW, design day 3x1055kW chillers WBT = 20°C WSE operation < 4.4°C WSE approach 1.7°C WSE delta 2.8°C CHWST = 8.8°C CHW DELTA = 6.7°C CHILLER 100% = 5.9 COP CHWP head = 43m CWP head = 24m CW delta = 5.6°C

In chilled water plants, a water-side economiser uses the evaporative cooling capacity of a cooling tower to produce chilled water and can be used instead of the chiller during the winter months. This "free" cooling of the chilled water can dramatically reduce the energy consumption that would normally come from operating the chiller. A plate-and-frame heat exchanger can be used for efficient heat transfer and to separate the water from the cooling tower and the chilled water to prevent cross-contamination.

Economisers are best suited in climates where the wet bulb temperature is lower than 13°C for 3,000 hours or more.

The pre-cooling coils and water-to-water heat exchangers used as part of a water economiser system should have a water-side pressure drop of less than 5m, or a secondary loop should be created so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (non-economiser) mode.

Water-side economisers can be integrated with the chiller or non-integrated. Integrated water-side economisers are generally considered the better option because they can pre-cool the water before it reaches the chiller. Non-integrated water-side economisers run in place of the chiller when conditions allow.

We shall examine this later in the paper when we compare traditional control systems versus a dedicated plant control. In addition, using variable speed drives on cooling tower fan motors and water pump motors is beneficial during times when the heat rejection load is lower.

The purpose of the chilled-water pump is to circulate chilled water within the loop. Generally, the pump must overcome the frictional pressure losses caused by the piping, coils, and chiller and the pressure differential across open control valves in the system. The pump, while working at the system static pressure, does not need to overcome this static pressure. For example, in a forty-story building the pump need not overcome the static pressure due to those forty stories. The pump is typically located upstream of the chiller, however it may be anywhere in the system, provided that the pump:

1. Meets the minimum pump net positive suction-head requirements. That is, the system pressure at the pump inlet must be both positive and high enough to allow the pump to operate properly;
2. Maintains the minimum dynamic pressure head at critical system components (usually the chiller). If the dynamic pressure head is not high enough at these components, proper flow will not be established through them;
3. Accommodates the total pressure (static head plus dynamic head) on system components such as the chillers' evaporator, valves, etc.
4. Should not exceed the chiller barrel pressure limits (usually on larger building with high pressure systems).

Selecting the pumps for a large or strategic project should be more than simply looking at existing drawings and entering the flow & head from the pump schedule. For original project selections or to check that the schedule produces the best customer LCC (Life Cycle Cost) look at pump numbers in parallel one number less or more than the specified number. A better combination than specified should be discussed with the system designer for the best customer value.

One of the many Design Envelope values is that there is generally inherent increased flow & head capability, above the design conditions, to the maximum speed and /or motor size. One use for this extra capability for customer value is to review the added flow capability at the design head. By understanding the maximum flow there is a possibility that N+1 flow (The flow that the number of operating and standby pumps, should one pump fail) may be produced by the number of operating pumps only. For example, the maximum

Design Envelope model flow at the design head is 150% of the design flow, then 3-pumps will produce the equivalent of 3+1 selected conventional pumps, saving the pump, motor, controls, piping, SG, FTV costs + electrical & labor for installing that unit. The required added flow capability ratio will reduce as the number of operating pumps increase.

Effect of condenser-water flow rate

Since the condenser is a heat exchanger, it is sensitive to water flow rate. For example, excessive flow may result in high water velocity, erosion, vibration, or noise, while insufficient flow reduces heat transfer efficiency and causes poor chiller performance. Therefore, condenser-water flow through the chiller should be kept within a specific range of limits, except during transient start up.

However, the same selection thoughts applied to the chilled water pumps can be applied to the selection of condensing water pumps.

Considering Controls …

Armstrong can offer two control panels for chilled water plant control; IPC11550 and the Opti-Visor.

Both employ the demand-based control methodology which is able to further enhance tower performance with sequences to trade off lower leaving tower water temperature against chiller lift for the load and weather situation being experienced. Both controllers will also sequence parallel primary variable pumps based on best efficiency staging. This is all achieved through advanced control sequences listed below:

1. Demand based control
2. Natural curve sequencing
3. Equal marginal performance principal.

In order to calculate the savings, an energy audit (or energy analysis) can be completed with a plant configuration shown at the beginning of this guide.

Using the following conditions:

- Assumed building load profile (building load vs. hours of operation)
- Specific regional weather data and wet bulb temperatures vs load.
- The building design conditions (tonnage, number of chillers, size of each chiller, type of each chiller, etc.),

The tool can estimate savings between a Base-Case configuration vs. and a Final-Case configuration. For more information on the tool please contact Armstrong Project Engineering Group – Technical Support.

PLANT AUTOMATION / CONTROL STRATEGY DESIGN ENVELOPE VS. CONVENTIONAL

Design Envelope plant	Conventional plant
Design Envelope VIL pumps with integrated controls	Pump drives on the wall
OPTI-VISOR	BMS controls • Chiller start/stop • Chilled water pump start/stop • Cooling tower start/stop • Condensing water pump start/stop • Bypass valve
ECO*Pulse	

WATER COOLED DATA CENTER CHILLER PLANT WITH ECONOMISER AND STORAGE TANK BASE CASE INSTALLATION

Utah, USA

Technical details:

- Three variable speed Chillers that produce chilled water (3 x 1055 kW units), design day tonnage of 2110 kw of cooling
- Four Zones of Loads with differential pressure sensors, often satisfied by coils, that transfer heat from air to water
- Four chilled-water distribution pumps (n+1) and pipes that send chilled water to the previously mentioned loads
- Four condenser-water pumps (n+1), pipes, and three variable speed cooling towers that reject heat
- Controls that coordinate the operation of the mechanical components together as a system. We will assume a typical capacity based control strategy operated by a Building Management System (BMS).
- Water side economisers to precool some or all of the return water in a chilled water loop with the cooling tower, substantially reducing or even eliminating the need for mechanical cooling at low temperature periods. Through the use of plate and frame heat exchanges the building heat is transferred from the chiller water loop into the cooling tower loop and then dissipated to the atmosphere.
- Storage tank to offset some energy consumption expense during peek hour chilled water generation

And now the addition of Design Envelope plant controls ...

We can simulate an annual energy consumption and create a return on investment calculation on the savings.

With an all variable speed plant, we can estimate the OPTI-VISOR can perform around 5.9 COP (or better) with annual savings of around 329,800 kWh. Converting to electricity cost, we could estimate that savings to be around £12,989.

Please note that the OPTI-VISOR does not include programming for free-cooling. That must be completed by BMS. The weather data for Salt Lake City, Utah shows a drop below 4.4°C WBT for 2 months (Dec, and Jan). Essentially, the OPTI-VISOR will not be operating for this time, since it was indicated that mechanical cooling will not be in operation under temperatures < 4.4°C WB. The savings generated are thus for only 10 months of the year.

Looking at Table (1), we can summarise the above analysis.

Table (1) Summation of Chiller Plant Analysis

Item	Qty	DE plant (£)
Chiller pumps	4	£ 17,354
System VFDs	4	Incl
Cond water pumps	4	£ 15,611
CW VFDs	4	Incl
Elbow & spool	4	Incl
Check valve & Isolation	4	Incl
Controls		£ 78,768
Total installed cost		£ 111,732
DE savings		-£ 21,949

We can use the subsequent tables to analyse each area of importance in terms of Installed cost, life cycle costs and risk management.

LOWEST INSTALLED COST

Savings area	Design Envelope plant installed savings
Material & installation	(£ 21,661)
Time (labour)	£ 9,734
Power infrastructure	40 kW (54 hp)
Space	£ 22,974
Civil structure	£ 1,085
Commissioning & call backs	£ 788
Total installed savings	**£ 12,986 (29%)**

The benefits of Armstrong Design Envelope pumps:

- The Vertical In-line design eliminates the need for inertia bases, housekeeping pads, and flex connectors and reduces piping requirements.
- The Integrated intelligent controls eliminate separate mounting of variable frequency drive (VFD) as well as procurement, installation (incl. wiring), calibration and upkeep of differential pressure sensor.
- The Vertical motor positioning requires up to 60% less floor space compared to other pump configurations.

LOWEST OPERATING COST

Savings area	Design Envelope plant operating savings (annually)	
Energy		£ 12,982
Maintenance	(£50/hour)	£ 1,182
Reliability	(increased availability)	20%
Water		£ 1,247
Operator labour	(£50/hour)	N/A
Target Mtce avoids failure (E*P)		N/A
Total operating savings		**£ 15,418 (23%)**

The benefits of Armstrong Design Envelope pumps:

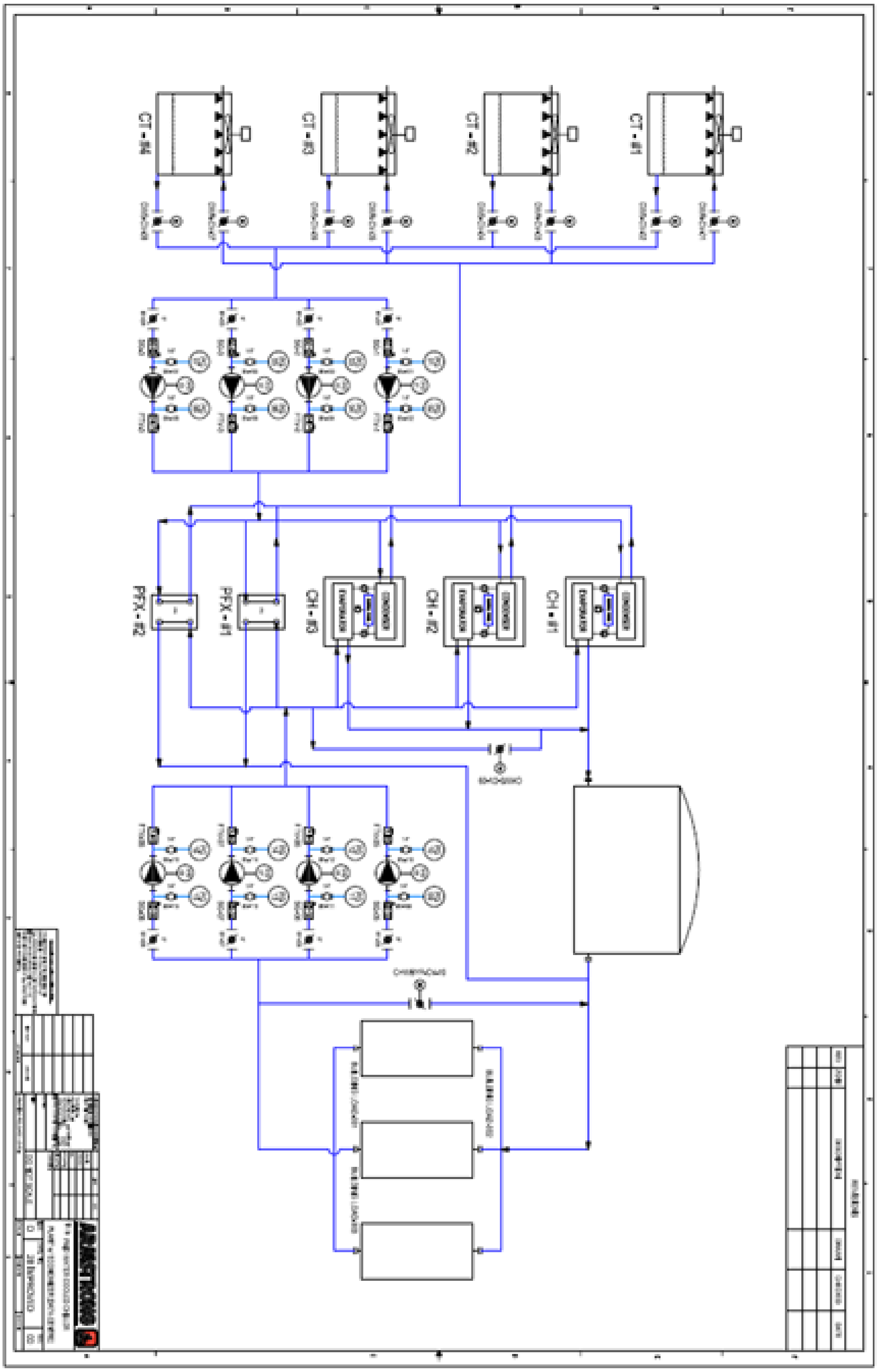
Considering the variable frequency drives are located on the motors – as part of the Design Envelope feature, harmonics that may be produced with long cabling lengths are eliminated.

The Opti-Visor controller, tested at the factory also provides risk mitigation compared to the conventional building management system (BMS).

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	£ 14,440	0.9%
Owner (capital projects)	Inevitable design changes by different stakeholders	£ 7,220	0.5%
Owner (operations and maintenance)	Energy and operational savings not achieved	£ 15,097	1.0%
Engineer	Reputation deterioration and losing new business	£ 22,974	1.5%
Mechanical contractor	Commissioning delay and payment delay of hold back	£ 7,220	0.5%

PROCESS & INSTRUMENTATION DIAGRAM



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