THE INSTITUTE OF REFRIGERATION

A Cooling Case Study
Heathrow Terminal 5 Ammonia Chillers

by

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Abstract

The paper describes the design and construction of the Energy Centre for the Terminal 5 development at London's Heathrow airport. T5 consists of a series of large buildings and infrastructure with their own utility services. All heating water, cooling water and domestic water is supplied by a central energy centre.

The paper further describes the ammonia chillers selected for the project from the perspective of the supplier and provides an insight into:

- the challenges presented by the cooling needs of the Terminal 5 project
- the development and management of the T5 project building services by SPIE Matthew Hall
- the selection and application of chillers for the project and why ammonia refrigerant was chosen
- the design concept, construction and testing employed

Heathrow History [1]

London Heathrow is the UK's largest airport and the world's busiest international airport, carrying over 68 million passengers and 1.3 million tons of cargo each year.

The site's aviation history began during the First World War and the location remained a military airfield until 1919. It then became the privately owned Great Western Aerodrome and was largely used for test flying until it was requisitioned by the Air Ministry to be developed as a major transport base for the Royal Air Force in 1944. The war ended before the work was completed.

With the prospect of a large expansion in civil aviation, London needed a large, modern airport. Croydon Airport, London's civil aviation facility since the 1920's, was unsuitable for expansion. The partly-built site at Heathrow offered the ideal location. One runway was ready for use and when the Ministry of Civil Aviation took it over in 1946, a tented terminal was quickly erected allowing operation to begin. By 1947 three runways had been completed and a permanent building arose in the central area at the start of the 1950's

As air traffic grew Heathrow Airport found itself with an ever-increasing demand for passenger facilities. The Queen inaugurated a new building in 1955 (Terminal 2) and the tunnel which provides the access to Heathrow's central area was opened. Next came the new Oceanic terminal handling long-haul carriers, a function it still performs as Terminal 3, followed by the opening of Terminal 1 in 1968. Increased congestion in the central area led to the birth of Terminal 4 in 1986 on the south side of the airport.

Following the longest public inquiry in British planning history – a total of three years and 10 months – the Government gave approval in November 2001 for BAA to build a fifth terminal at Heathrow, but it was not until January 2003 that the London Borough of Hillingdon finally granted consent and construction began on the Terminal 5 site, which is situated within the airport's existing boundary. When fully complete in 2011, the new terminal will have the capacity to handle 30 million passengers a year.

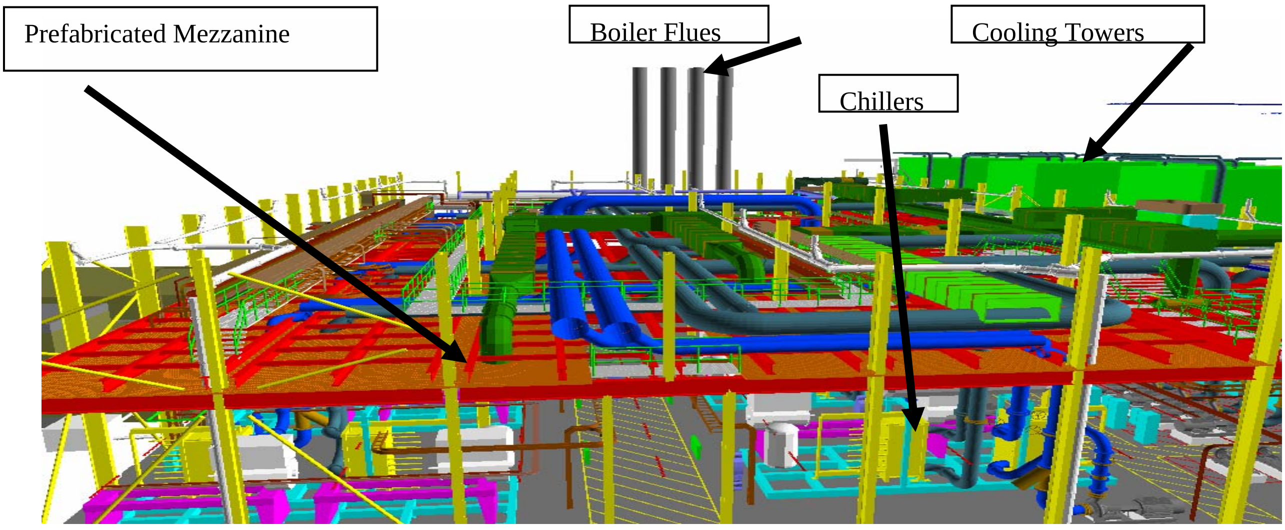
September 2005 saw the Terminal 5 'topping out' ceremony, to celebrate completion of the spectacular building structure, and T5 was officially opened by the Queen in March 2008.

The Terminal 5 Project

Energy Centre

Heating and cooling the new terminal buildings at Heathrow airport's Terminal 5 development is undertaken by a dedicated energy centre, which provides continuous supplies of hot and chilled water for heating and air-conditioning respectively. The hot water is provided by a combination of a local combined-heat-and-power source and natural gas boilers, whilst the chillers are powered by high-voltage electricity.

The centralised distribution of these services to the main terminal building, its satellites and ancillary areas was considered to be the most effective solution based on construction, commissioning, operations and energy efficiency considerations. It also enabled flexibility in terms of future development.



The Energy Centre ensures effective & sustainable supply of services to the T5

The energy centre project was design and built by SPIE Matthew Hall (formerly AMEC), working in conjunction with other contractors, the principal designer PB Power and the client BAA's technical team. It involved the large-scale off-site modularisation of mechanical and electrical services and supporting structure, and included fast-track on-site assembly methods and technology. It also provided an early opportunity to test the T5 information technology network and control systems integration.

Definition and project requirements [2]

When the engineering design for the energy centre started in 1998, assessments were made on the potential use of renewable energy and combined heat and power (CHP). It was concluded T5 should not have a dedicated CHP system, but that a single CHP plant serving the T5 and central terminal area (Terminals 1, 2 and 3) would be more appropriate – though in the event this did not proceed. However, during the commissioning of the energy centre, it proved possible to integrate a CHP connection from the nearby Thames Valley Power plant that also supplied the airport cargo area.

The scope of the energy centre project comprised:

- free cooling feature
- centralised hot water
- centralised chilled-water plant
- heating, cooling and associated system distribution networks
- gas supplies
- high-voltage electrical supplies to chillers
- water treatment
- heat-rejection facilities
- controls and information technology networks
- CHP supplies
- support systems such as lighting and fire alarms
- chilled water store

The design was influenced by the strategic restriction on height and the then-new Building Regulations. In addition to the main plant rooms, the building includes a control room, stores area, workshop, offices and support accommodation for the operator Heathrow Airport Ltd.

The overall design encompassed the heating and cooling demands for the various buildings, which required close co-operation with other design teams across the project. The design process established the optimum operating temperatures, pressures and controls philosophy to reduce life-cycle costs. A full energy metering system has been incorporated to monitor consumptions of all service provisions.

Delivery of the engineering systems was largely based on build off-site technology. Large integrated sections of the works – incorporating mechanical and electrical systems and equipment and, where appropriate, structural elements of the building framework – were manufactured and delivered to site as complete modules.

In parallel, important elements of off-site testing were integrated into the process to assist in verification of plant and equipment performance. This also enabled the incorporation of manufacturers' input to design and fabrication processes, ensuring good technical co-ordination, physical fit and parallel manufacturing sequences.

Standards of Design

The design of the energy centre was carried out to the client's engineering guidelines, EN standards and other appropriate industry guidance such as Building Services Research and Information Association reports, Chartered Institution of Building Services Engineers guidelines and energy best-practice publications.

Systems design was based on the fundamental criteria of:

- energy provision is in the form of hot water for heating and chilled water for air conditioning
- provision from a single energy centre

The key requirements for heating and cooling demands were for business continuity of the T5 operations, which were established by the design teams for each separate building.

The complete process of design verification and sign-off was conducted via project procedures including quality plans, risk assessments and technical audits. This ensured the complete design-to-commissioning process was documented, transparent and structured.

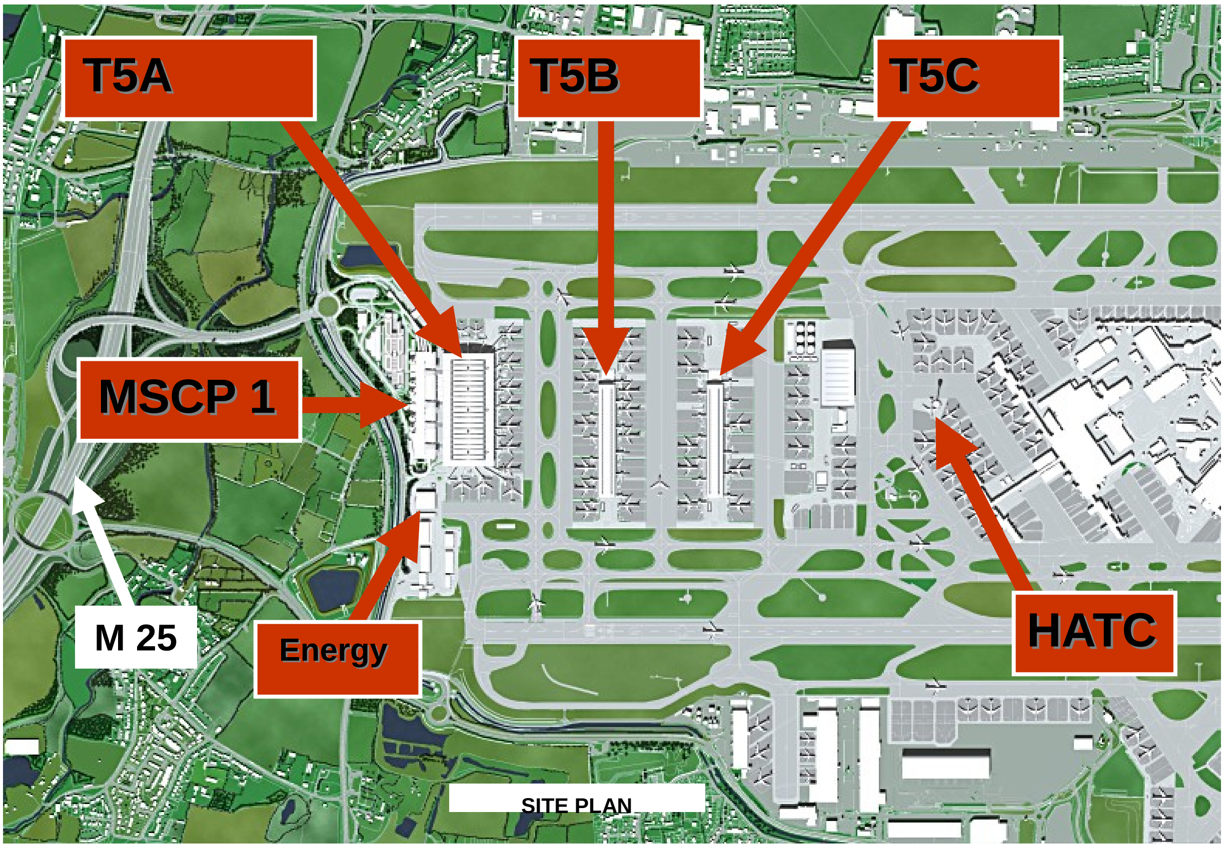


Figure 1: Area plan of campus showing location of energy centre

The primary energy supply to the centre was selected as natural gas for heating and high-voltage electricity for power.

Development Stage
This stage incorporated wider considerations of manufacturing, construction and commissioning. Key members from the design definition stage were included, enabling buildability to be taken into account and ensuring learning from the design process was effectively taken forward.

Some of the key deliverables from the detailed development stage were:

- detailed activity programmes, inclusive of build off-site technology
- milestone definitions, including those from the design definition stage
- change-management assessments
- detailed risk-management assessments
- buildability reports
- cost and time evaluations
- testing and commissioning plans
- procurement documentation
- three-dimensional drawings and fabrication details
- handover plan
- maintenance considerations and associated technical reviews, involving appropriate client representatives
- development of the construction health and safety plan
- commissioning process

The philosophy through each stage of the programme was to eliminate health and safety risks during construction, commissioning and operations. Consideration of the project's eventual demolition was also included.

Technical Content
The energy centre is located to south west corner of the T5 site (Figure 1). The heat rejection equipment located within the roof and the main plant is located at the ground floor level with distribution occurring at mezzanine level.

The interconnection is via a series of below-ground tunnels housing:

- chilled-water pipes
- heating-water pipes
- potable-water pipes
- grey-water pipes
- high-voltage power cables

To support the main plant, the hydronic pumping arrangements are as follows:

Heating - Primary heating pumps and circuit serves the boilers with secondary transfer pumps to the main terminal T5A, satellite terminal T5B and future satellite T5C. There are secondary exchange plant rooms within the terminal buildings housing interface-plate heat exchangers, which step down the primary supply temperature from 95°C to 72°C with secondary pumps within each building for general distribution.

Chilled water - There are primary pumps associated with the chillers, coupled up by a common primary pipe work circuit. Secondary pumps in the energy centre circulate the chilled water directly to each point of use in each terminal building.

Delivery Philosophy - Following the design definition and design development stages, the delivery of the energy centre project was conducted through the following key stages:

- fabrication design
- manufacturing
- assembly
- commissioning
- integration
- handover

The philosophy was to give due consideration to each of the above stages and achieve good integration between designers, manufacturers, engineers and project management functions co-located on the T5 site. All parties were working to the unique and open style of the T5 agreement, which sets out how all parties should work together to common objectives and deliverables.

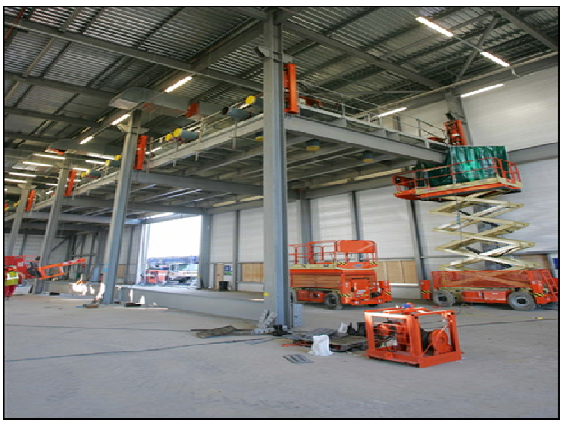


Figure 2: Prefabricated 6m by 30m mezzanine floor modules

Figure 2 shows one of the five prefabricated mezzanine floor modules being stand-jacked into position inclusive of integrated mechanical systems. The benefits of the build off-site methodology are as follows:

Safety - Installing mechanical pipe work up to 600mm diameter by traditional means at high level would have significantly increased construction health and safety risks.

Time - Jacking of the 6m by 30m sections as shown in Figure. 2 is carried out in a matter of days as opposed to many weeks of traditional construction methods. The overall benefit was calculated to be around four months for the complete project.

Interfaces - The major modules incorporated steel beams that not only supported the modules but also became part of the building structural frame, reducing the amount of steelwork needed.

Cost - Overall cost benefits were achieved, by reducing the length of the critical path in the programme and allowing earlier delivery of key plant items to site due to a faster availability of associated space under the mezzanine floor and getting the plant on line early.

The use of three-dimensional modelling was an important feature within the delivery process. Not only was this used to develop fabrication and assembly details, but the model visualisations facilitated better risk assessments, improved understanding of the assembly sequences and a better method of communicating to all parties involved.

Energy Demand - The demands from the terminal buildings are varied and quite dramatic in their seasonal pattern the peak cooling demand changes dramatically from low to high. Whereas two or three compressors are needed for the majority of the cooling season, this rapidly increases to the full eight compressors at peak condition for a relatively shorter period of time. The controls and pipe work strategy accommodates these variations.

To minimise the energy consumption by the energy centre, the following technology has been incorporated into the design:

- efficient plant selections
- heat recovery from the lead boiler
- incorporation of heat supply from CHP plant
- efficient pump selections with energy-saving controls incorporated
- high-efficiency plate heat exchangers
- heat exchanger coupled to one dedicated tower/refrigeration plant configuration to provide an amount of free cooling facility (i.e. using this tower to cool the return chilled-water line from the terminal buildings when appropriate to utilise the facility)
- variable-speed drives on all associated pumps
- variable flow systems

Commissioning and Handover

The commissioning process was put in place during the design development phases. The process was based upon a number of key stages delivered through 'gateways'. These gateways enable the integration of a number of related sub-systems into a common and auditable process (Figure 3).

Each of the gateways incorporated a detailed schedule of requirements that had to be satisfied and signed off prior to the move to the next commissioning stage. The client arrived at the handover stage, having been involved in every preceding section of the delivery process.

The handover plan was not just about a formal transference of responsibility and information; the process encompassed all of the following:

- record information and drawings
- maintenance documentation
- training schedules for client's operations staff
- operational training for systems
- risk residuals
- witnessing of commissioning results and site acceptance tests
- sign off inspections by the building control representative
- asset coding schedules

All of these were co-ordinated within a specifically drafted handover agreement, so that a summary of all the documentation references is located in place.

The key to the handover was to develop the client's operational staffs' knowledge and information so that they could operate and maintain the systems effectively, safely and with understanding of the dynamics of the engineering solutions.

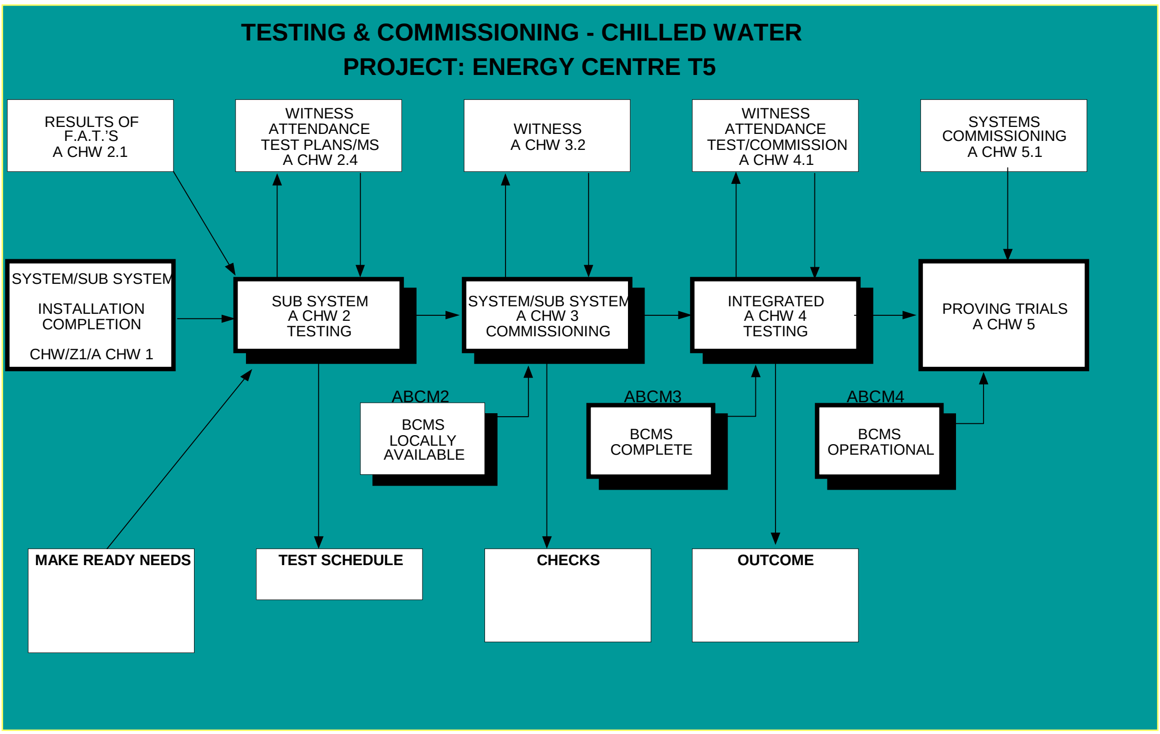


Figure 3: The Commissioning process was based on a series of key gateways

The Chillers

In 2003 Sabroe, via its parent Johnson Controls (formerly York International), were invited to participate in the design and development of the chillers to serve the AC services for the T5 project.

The assessment involved a number of stages supervised and assessed by SPIE Matthew Hall these included:

- Chiller performance and efficiency
- Main drive, motor voltage & starting
- 'Worst Case' Ammonia leak assessment
- Machinery room design (heat gains, ventilation, emergencies)
- Noise level
- Control system
- Maintenance requirements and proposals
- HAZOP study

The primary considerations for the chillers were that they should offer the maximum operation efficiency, proven design and that they should be completely assembled and tested at the manufactures works prior to shipment to ensure the minimum site installation time.

Two of the 4,6.6 MW chillers

The thermal load

The HVAC design engineers had conducted the evaluation of the chilled water load profiles. Typically, air-conditioning applications have high peak loads, but low average loads and this is true for the Terminal 5 profile. Such profiles result in a high capital cost refrigeration plant standing idle for significant periods or substantial periods of 'part load' operation.

The high capital cost is exacerbated if additional capacity is installed for redundancy. Consequently, the design team recommended that standby capacity was not installed, but to reduce the impact on one or more units being unavailable, a sufficient number of units should be installed. Moreover, the design of the chillers should incorporate features to limit the possibility of downtime due to plant failure or maintenance.

A chilled water storage system was incorporated into the design to reduce the installed chiller capacity by 'peak lopping', as well as increasing the possibility of free cooling by capturing and storing night time and low ambient temperature cooling opportunities.

Phase 1 – Terminal 5 Cooling Capacity Profile			
Quantity	*Type*		*Rating*
1	Thermal Chilled Water store		2.6 MW (8%)
4	NH3 Chillers		6.7 MW (23%)
Plant available	*% Peak Load*	*Hours / year demand not met*	*% Annual kWh not supplied*
Store + 4 Chillers	100	0	0
4 Chillers	92	11	0.03
3 Chillers	69	97	0.46
2 Chillers	46	552	2
1 Chillers	23	4480	21

Table 1: Terminal 5 cooling capacity profile

Table 1 [3] shows the installed capacity profile for the project. It can be seen that more than 99.5% of the annual demand can be met with the store and one chiller unavailable and, hence, the probability of any impact on the comfort level in the terminal is very low. Moreover, it is very unlikely that the store would physically fail; in practice it is more likely that a circulation pump could fail, however, the provision of run and stand-by pumps overcome this.

Ammonia [5]

Ammonia was chosen as the primary refrigerant because of its superior thermodynamic and transport properties. It offers many desirable qualities:

- A naturally occurring, bio-degradable chemical.
- Part of the Earth's natural nitrogen cycle
- Short atmospheric lifetime
- Does not contribute to Ozone Depletion or Global Warming

- Very efficient refrigerant. High specific cooling capacity, heat transfer, high COP, low TEWI.
- Very easily detected
- Has been safely used for over a century

Moreover, ammonia is a 'future proof' refrigerant from an environmental view point. It is of course a toxic alkaline and, if not contained in a properly constructed plant, potentially lethal to humans. However, ammonia can be safely contained and has been widely used in thousands of refrigeration plants for over a century. It is well understood by refrigeration engineers and requires no special engineering beyond the well established thermodynamic, mechanical and material engineering technologies.

The Chillers

The Sabroe range of PAC (Packaged Ammonia Chillers) was introduced in the mid 1990's following development and competitive availability of laser welded plate heat exchangers. The benefits of plate heat exchanger technology had been understood for many years, but the risk of ammonia leakage from earlier gasketed exchangers had been an impediment to their use.

The basic chiller is a simple, so called, flooded chiller as depicted in Figure 4. It comprises a compressor unit, plate heat exchanger condenser, float regulator and plate heat exchange evaporator. In essence, it is the simplest of vapour compression refrigeration systems. The reality is a little more complex, but not particularly so. A total of four unit's identical unit were delivered for the project (Figure 5).

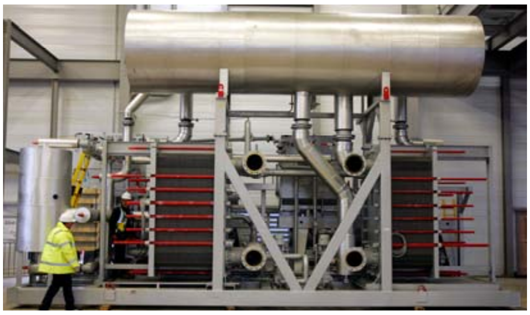


Figure 5: A terminal 5 chiller unit

The condenser and evaporators are Alfa-Laval plate heat exchangers. Sabroe has had a long cooperation with Alfa Laval in the development and application of their laser welded cassette heat exchanges for ammonia chiller applications. Figure 6 shows the typical plate construction. The cassettes are mounted in a support frame to provide the required heat exchange surface area. The secondary cooling medium is circulated through the gasketed section of the heat exchanger and the ammonia through the enclosed section of the welded cassettes. The gasket arrangement, including a double seal at the interconnecting portholes, prevents secondary fluid and ammonia escape. Moreover, if the porthole gasket at the ammonia interconnection were to fail, there is a clear leakage path to atmosphere to avoid contamination of the secondary fluid. Various grades of stainless steel or titanium plates are available. The T5 units utilised ANSI 316 stainless steel.

The mechanical design of these heat exchangers has been proven over many year of operation and the construction and test, including a final helium leak test, ensures the utmost security.

The evaporator is mounted together with a

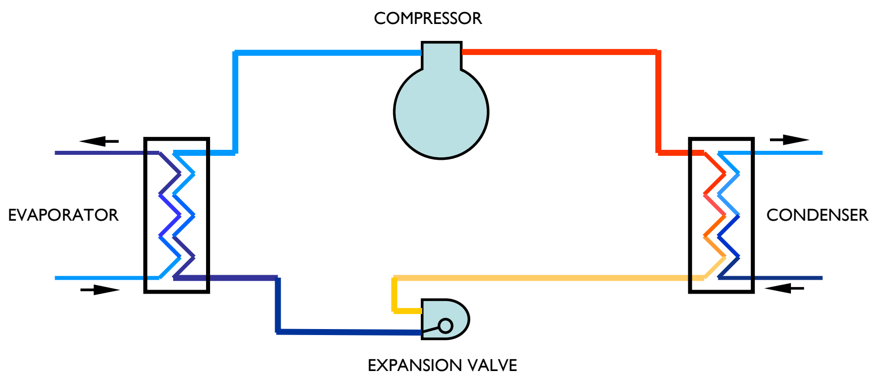


Figure 4– Basic PAC Chiller Function

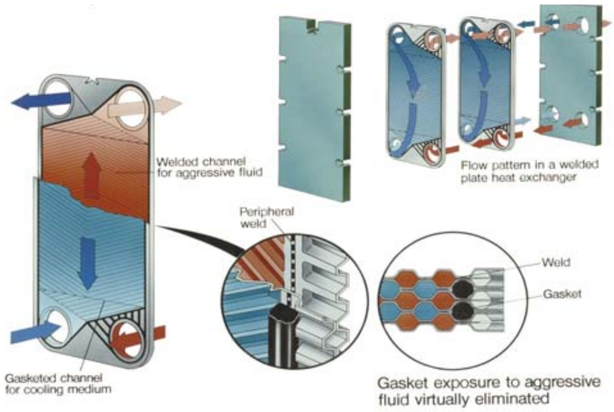


Figure 6: PHE plate arrangement

suction/liquid separator to provide a natural circulation, flooded operation. The use of a thermosyphon system allows close approach temperatures to be utilised. Importantly, this means the total heat exchange surface may be utilised at part load and the LMTD will reduce with reducing load. This design ensures a 'wetted' heat exchange surface to maximise the heat transfer efficiency and the suction separator disengages liquid droplets entrained in the ammonia vapour leaving the evaporator, ensuring that only dry saturated vapour is drawn back to the compressors.

The condenser was to be water cooled for this project. As for the evaporator, the LMTD in the condenser will reduce as the thermal load decreases. The combined effect is to improve the part load performance of the unit (Figure 7).

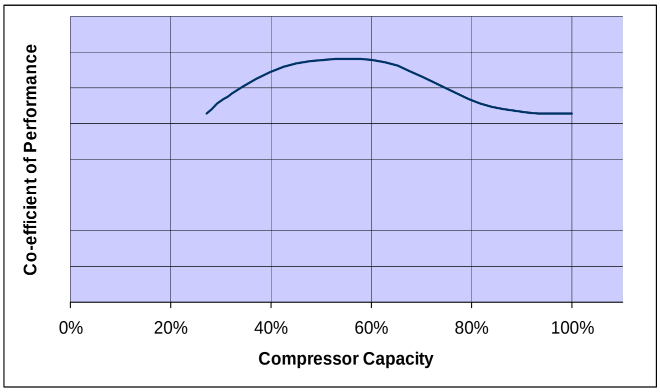


Figure 7: Typical part load characteristic for PAC chillers

Within the PAC series it is possible to select reciprocating or screw compressor units, either with single or dual compressor options. The capacity for the T5 project required compressor units from Sabroe's Uniscrew range and two independent compressor units per chiller unit were chosen to provide the best load management and maintenance flexibility. Each oil injected compressor unit incorporates independent oil separation, cooling, filtration and temperature management systems. The oil separators incorporate high efficiency coalescing elements to reduce the oil leaving the compressor unit to minimal levels, whilst the oil system ensure the oil delivered to the compressor is maintained at the correct temperature and quality.

Independent water cooled oil coolers are incorporated for each compressor unit to ensure that the oil is maintained at the required operating temperature. This arrangement allowed for one complete compressor unit to be maintained whilst the other remains in operation. The cooling water circuits are allowed to operate at design flow to minimise fouling, but the oil temperature is accurately regulated by a thermostatic three-way valve in the oil circuit.

For increased efficiency, each chiller unit operates with a common 'open flash' economiser. The economiser is an established method of improving the thermodynamic performance of a screw compressor by expanding the main liquid stream into an intermediate vessel and drawing the 'flash gas' generated into the compressor via an intermediate port which is closed to the suction side. There is no reduction to the suction volume, thus the mass flow entering the compressor is unchanged, but the cooled liquid stream entering the evaporator has an increased enthalpy of vaporisation and, therefore, an increased total cooling effect. The added gas volume imposes additional compression power, but there is a thermodynamic advantage. In this application the economiser pressure is regulated to maintain a minimum pressure differential over the evaporator.

The chillers operate with a, so called, critically charged system – meaning that they contain a minimum quantity refrigerant. The flow or refrigerant is controlled by a liquid level sensor mounted at the condenser outlet which allows all condensed liquid refrigerant to pass through to the economiser. Equally, a similar arrangement in the economiser allows liquid to pass on into the evaporator. The flow is regulated through appropriate regulating valves.

Albeit, the compressors have very low oil carry-over, there will be a small quantity of oil leaving the compressor units and, if not recovered, will accumulate. Being heavier than ammonia, the oil is collected in a vessel placed at the bottom of the evaporator. The vessel is equipped with a float switch having a precisely weighted sensor that will float on oil, but not in ammonia. Consequently, when sufficient oil has accumulated, an automatic ejection system returns the oil to the operating compressors.

Each compressor unit is equipped with Sabroe's Unisab II microprocessor controller. This monitors, controls and supervises all of the functions of the unit. All pressures, temperatures, current, etc are continuously monitored and regulated to maintain stable operation. Each Unisab II may operate 'stand alone' or may communicate with others for optimum part load capacity regulation. Moreover, there are a variety of external communication options, enabling each package to be integrated into the overall BMS control for the installation.

PAC 283L(T) Chiller Unit Operating Data	
Design Cooling Capacity	6660 kW
Power consumption	2 x 618.4 kW
Condenser Rejection	7421 kW
Oil Cooling Duty	2 x 243 kW
Full Load Coefficient of Performance	5.38
Cooled Water Inlet Temperature	14.0° C
Cooled Water Outlet Temperature	5.5° C
Cooled Water Flow	676 m^3/h
Cooling Water Inlet Temperature	29.0° C
Cooling Water Outlet Temperature	35.0° C
Cooling Water Flow	1074 m^3/h
Oil/Motor Cooling Water Flow	2 x 38.4 m^3/h
Drive Motor (ABB 11 kV)	2 x 750 kW
Shaft speed	2970 rpm
Ammonia charge	1370 kg
Oil Charge (PAO 68)	930 kg
Operating weight	50000 kg

Table 2: Terminal 5 chiller operating data

The drive motors of this project were carefully considered. The Terminal 5 Energy Centre had 11 kV, 3.3 kV and 400 V supplies. Fixed and variable speed drive options were examined. A detailed analysis of power supply, starting options and part load operation concluded that, for this project, 11 KV motors with DOL starting secured the lowest realised cost. Water cooled motors were chosen to reduce the ventilation requirements for the plant rooms and the motor cooling systems integrated into the compressor oil cooling circuits.

The units were completely assembled in Sabroe factory in Aarhus, Denmark. The design, construction and testing followed Sabroe's ISO 9000 approved QA procedures and complied fully with EU and PED/EN 378 requirements. After assembly, each unit was subjected to a Factory Acceptance Test. The Sabroe factory already had an extensive end-of-line test facility for its normal production of PAC units and this facility was extended to accommodate the full performance testing of the first of the T5 units. This was only undertaken for the first unit, as it was necessary to utilise one of the actual 11 KV starters from the project to be able to operate both compressors simultaneously. The remaining units were fully tested, but only operating one compressor unit at a time using the test centre equipment.

The physical size of the units meant that they could not be transported from Denmark to England as fully assembled units. Consequently, they were manufactured with flanged connection allowing each unit to be separated into three sections for shipping. After testing, the refrigerants were removed from the unit and the sections separated. Each section was sealed with blanking flanges, evacuated and charged with a holding charge of dry nitrogen. Upon arrival at site, the sections were off loaded and reassembled in the plant room by Johnson Controls installation team. The units were pressure tested, evacuated and charged with the refrigerant and oil. This design of unit operates with a low refrigerant change.

The site

Water was selected as the appropriate cooling medium for the chillers. A common cooling tower water circuit is utilised to ensure all towers are available to whichever chillers are operating. Cooling water was supplied to each unit by the energy centre pumps and regulated according to the demand on the chillers. Each chiller package incorporated auxiliary water pumps to circulate cooling water through the

Chiller Unit Shipping Data			
Weight	Length	Width	Height
Suction Separator Section			
4700 kg	5100 mm	2300 mm	2000 mm
Heat Exchanger Section			
17300 kg	9600 mm	2150 mm	3950 mm
Compressor/Motor Section			
21500 kg	9650 mm	2700 mm	3800 mm
Assembled Unit Dimensions (net)			
43500 kg	9650 mm	4113 mm	7000 mm

Table 3: Terminal 5 chiller shipping data

compressor oil cooler and motor cooling circuits.

Each chiller unit was to be placed in its own acoustic enclosure. A detailed sound analysis was provided for the chiller unit enabling the enclosure to be appropriately constructed. Sufficient cooling tower capacity was installed to reduce the impact of single unit failure.

A detailed analysis of the 'worst case' ammonia escape was conducted. The potential heat gains were estimated and the maximum concentration of ammonia in the exhaust air calculated. Additionally, the heat loss form the pack was calculated to determine the minimum ventilation rates required. It was possible to determine the appropriate ventilation rate for each unit compartment to maintain a sensible room temperature and for emergency ventilation.

Ammonia scrubbers were incorporated into extract system to reduce the concentration to acceptable limits in the event of leakage. The scrubber consisted of a low pressure shell with packing through which the ammonia/air is extracted. The packing is soaked with a dilute acid solution by a series of nozzles.

Each unit enclosure was equipped with ammonia detectors to automatically trigger the emergency ventilation and unit electrical isolation in accordance with EN 378. The extract system was equipped with run and stand-by fans, dual fed from independent transformers connected to separate primary circuits.

A HAZOPS was conducted for the Energy Centre, including the refrigerated water chillers, to evaluate the operation under normal, degraded and emergency situations. The study considered the effects of flow, temperature, pressure, corrosion, levels, toxicity, fire, noise and vibration. A systematic valuation method was imposed.

Conclusion

The energy centre lies at the heart of the £4.3 billion T5 development, ensuring the effective and sustainable supply of energy services to the terminal buildings.

The selected chillers demonstrate the optimisation of an integrated cooling system, whilst having regard for the environment and operating efficiency. They provided for the design demand for off site construction and testing, with minimum site installation and commissioning time.

The robustness of the design, build and commissioning processes has delivered a project that provides critical business continuity for the airport operator, airline operators and retail concessionaires.

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Acknowledgement

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The venue for the evening paper is London South Bank University, Nelson Haden Lecture Theatre, nearest entrance is Faraday Wing, Keyworth Street, London SE1 6NG

Presentation will take place in the Nelson Haden Lecture Theatre, nearest entrance is the Faraday Wing on Keyworth Street.

Public Transport

Train and Tube:

The closest stations are Borough, Waterloo, London Bridge , Elephant & Castle, all are within a walkable distance of the campus.

By bus - numbers 1, 12, 35, 40, 45, 53, 63, 68, 100, 133, 148, 155, 168, 171, 172, 176, 188, 196, 333, 344, 360, 363, 453, 468, C10 and P5.

Car

Parking in Central London is very difficult and it is not possible to park in the University grounds or the surrounding roads.