



Ark Continuity - Continuously Delivering high integrity data centres

Brunel helped build the Ark?

**Ark Continuity: a tour de force in low
carbon data centre construction**

Dr Ian F Bitterlin

PhD BSc(Hons) BA DipDesInn MCIBSE MIET MBCS MBIFM MIEEE

Mr Pip O Squire

MSc, DIC, BA (Hons) Oxon, CGeol, FGS



Ark Continuity delivers high integrity data centres for Government and Corporate occupiers. Ark is now building its data centre campus at Spring Park, Wiltshire with the first phase opening in November 2009. The facility will be one of the most secure, available and sustainable in Europe.

This document is one in a series of white papers prepared by Ark Continuity. If you would like further information, please contact Ark Continuity on 0845 389 3355 or visit www.arkcontinuity.co.uk

Copyright © 2009 Ark Continuity Limited. All rights reserved.

The information contained in this document represents the current view of Ark Continuity on the issues discussed as of the date of publication. Because Ark Continuity must respond to changing market conditions, it should not be interpreted to be a commitment on the part of Ark, and Ark cannot guarantee the accuracy of any information presented after the date of publication.

This white paper is for information purposes only. Ark Continuity makes no warranties, express or implied, in this document.

Ark Continuity may have patents, patent applications, trademark, copyright or other intellectual property rights covering the subject matter of this document. Except as expressly provided in any written licence agreement from Ark Continuity, the furnishing of this document does not give you any licence to these patents, trademarks, copyrights or other intellectual property.

Ark and Ark Continuity are trading styles of Ark Continuity Limited, registered in England and Wales number 05656968.

Head office: Hartham Park, Corsham, Wiltshire, SN13 0RP

Brunel helped build the Ark?

Ark Continuity: A tour de force in low carbon data centre construction

Summary

In the heart of Wiltshire a large data centre complex is being constructed by Ark Continuity. With 114MVA of available power; high capacity, diverse fibre connectivity to Bristol and Reading and 14.79 ha of development, Spring Park, Corsham, is set to become one of Europe's leading data centre campuses. The first phase of the initial data centre building, known as SQ17 (comprising 3,944m² of raised-floor Tier III accommodation), will be completed in November 2009. This facility, with high-efficiency power systems and free-cooling chillers, will offer a design yearly average PUE¹ of 1.45.

However, it is the next stage of development that will prove to be one of the most energy-efficient data facilities in the world – achieving a PUE of under 1.2 without introducing fresh-air into the data rooms. At the heart of the design is the use of a vast underground space at a stable temperature of 9°C (a highly secure, cool, subterranean complex) and an aquifer augmented by groundwater recharge from the surface facilities.

Historical Background

When the greatest engineer the world has ever known (Isambard Kingdom Brunel, who else?) decided to drive a running tunnel for his beloved Great Western Railway through Box Hill near Corsham in Wiltshire, he accomplished several things, not least of which included; setting world records for the longest railway tunnel and highest number of deaths² in a construction project, shrinking the journey time between London and Bristol, encouraging the two cities' clocks to be synchronised to GMT for the first time, accurately meeting (to within 2 inches) the eastern and western running tunnels after kilometres of drill and blast operation and, importantly for our story, he discovered a thick seam of pristine Bath Stone (Oolitic Limestone).

Box Tunnel, 3km long and 1:100 gradient, is still in full use today and carries the dual tracks of the First Great Western high-speed service between the south west, Bristol and London.

Even as his navvies blasted their way through the stone, Brunel (still only 30 years old³) realised that the quality of the stone matched the demand of the prestige buildings that were emerging in London, Bath and Bristol. Typical of his true entrepreneurial spirit, he tried to make a profit out of the tunnel spoil, however, trying to remove large cubes of stone rather than blasted rubble slowed the rate of penetration through the escarpment and he soon abandoned the idea of selling the stone as a bi-product and concentrated on building his railway.

¹ PUE, design Power Usage Effectiveness (PUE), is the ratio of the gross power delivered to the facility to the net power delivered to the IT load and an industry accepted metric of infrastructure 'goodness'. For fully loaded facilities PUE=1 is unattainable, 2.2-2.5 is the industry average and, for legacy systems, >3.0 is not rare.

² Over 100 navvies died during the 5 year construction project reflecting construction risk in the 19th Century.

³ It is a disputed tale that on Brunel's birthday, 9th April, the rising sun shines down the tunnel alignment

The shear scale of what happened next over the following seven decades would have impressed even Brunel and, there can be no doubt, he would have been in the technological vanguard of its latest incarnation had he lived on into our digital age.

Soon after the railway tunnel was completed in 1841, the stone mining (which had started in Roman times) began in earnest and by the 1920s more than 10 million cubic meters of fine stone had been extracted using the ‘room & pillar’ mining method (not requiring roof supports) at depths of between 40-70m in several separate mining operations under a vast expanse of the area of Corsham. In 1936 The War Office (led by Lord Beaverbrook) started to prepare for war in Europe and in 1940 the Spring Quarry mine was repurposed to become an underground manufacturing facility for Bristol Aircraft aero-engines and ‘power-egg’ assembly⁴. At its peak this ‘underground city’ housed 25,000 workers – secretly supporting the war effort in the heated and ventilated labyrinthine facilities⁵.

Spring Quarry – post WWII

Although war production ended immediately on cessation of hostilities in 1945 (the tax-payer having sunk £20m⁶ into the project), the underground was once again brought into use; this time as part of the Cold War infrastructure, forming a secure bunker for government in case of an all out assault on London. In 1964 Spring Quarry formed part of the Royal Navy stores facility as an annexe to RNSD Copenacre. By 1985 RNSD operations had relocated to Hartlebury, Worcestershire and Spring Quarry was finally closed. Being deemed as surplus to requirements, the property - 36 acres on the surface and 100,000m² of gross internal area underground (reaching far further than the surface footprint) - was put up for sale. It was purchased in 2000 with the status of a working mine which has been retained to the present day.

The underground ‘rooms’ lend themselves to numerous and highly secure remote data processing and storage applications. There is both lift and drift access to the main working level, which is around 30m below ground level. Ventilation via shafts constructed by the MoD is still functional, although the existing wartime fans will need to be replaced to support the future data processing/storage requirements. When the MoD was in occupation, the aquifer (laying above the Upper Fullers Earth strata but below the level of the mine) delivered peak flows of 158 litres/second of ground water at a seasonally constant temperature of 6°C. As well as a highly secure space, the underground also functions as a sustainable cooling resource.

The IT capacity plan

Initially, it is planned that 10MW of IT load will be installed in high-density rooms in the underground space. The disposition of the underground, although vast, encourages a layout of small vaults each between 100 to 200m² in size, with several vaults forming a discrete district. The design has been prepared to support high kW loads per cabinet (>20kW).

The M&E systems will be provided to Tier III classification of The Uptime Institute and follow, where applicable to EN Standards, the more detailed requirements of the ANSI Data Centre Standard TIA-942. In broad terms this will provide, in every M&E service, a minimum N+1

⁴ A complete engine in a pod for rapid replacement for aircraft needing an engine repair or refurbishment

⁵ For further reading: Secret Underground Cities, N J McCamley, Pen & Sword, ISBN 0 85052 733-3

⁶ Equivalent to £3.5Bn in 2008 using relative earnings

redundancy in an active delivery path plus a (non-redundant) passive path – resulting in the ability to carry out concurrent maintenance without load shut down.

Where the client permits, the rooms will operate at the latest ASHRAE TC9.9 Environmental Guidelines (e.g. $26^{\circ}\text{C}\pm 2^{\circ}\text{K}$ and 20-80%RH) to maximise cooling efficiency and minimise energy consumption. If a particular client demands a more traditional specification (e.g. $21^{\circ}\text{C}\pm 1^{\circ}\text{K}$ and 45-55%RH), then that would be accommodated on a ‘whole room’ basis – albeit at an energy premium.

Underground heat rejection

Despite the large scale of the workings, studies have shown that certain methods of heat-rejection (for a load of $10\text{MW}_{\text{thermal}}$) are impractical:

- Using air-flow alone would require over 40 air-changes per hour at peak ambient conditions which would result in air-speeds in excess of 30m/s
- Heat transfer into the surrounding rock is limited to less than $200\text{kW}_{\text{thermal}}$ per year after an initially high rate of $2\text{MW}_{\text{thermal}}$
- Heat rejection directly to the aquifer would be subject to Environment Agency discharge consent but assuming that all of the 158 litres/second at 9°C were available and the maximum outlet temperature into the drainage system was 16°C , the maximum heat rejection would be $3.8\text{MW}_{\text{thermal}}$ (less than free-cooling chiller plant on the surface, albeit continuous)
- Heat rejection into the percolated water recovered by groundwater recharge (rainfall and lateral flows totalling 10 litres/second) would only be $50\text{-}100\text{kW}_{\text{thermal}}$

However, by using conventional mine cooling technologies typically employed in “hot” mines, the site is able to take advantage of the available percolated water, the mine air flow and the copious plant space. Typically, the energy required to evaporate water is many times that required to heat the water without evaporation and it is this adiabatic process that mine cooling systems employ. For example, the constant evaporation of 4.5 litres/second of water within part of the mine space will absorb all of the $10\text{MW}_{\text{thermal}}$ IT load planned for the underground data centre space.

The technical solution is to be found in commercially available adiabatic coolers (where the energy to evaporate the water comes from the air itself, hence the term ‘adiabatic’). Couple this to rainwater harvesting and groundwater recharge, to allow the evaporation of more water without significant groundwater abstraction, and we have a truly sustainable cooling strategy that can support both the underground and surface data centre requirements at Spring Park.

The sustainable cooling system

The rooms will be pressurised with a minimum rate of (conditioned) fresh-air make up and high-performance precision air-handling units will operate in displacement mode (not using the raised floor as a plenum) in a ‘hard’ cold-aisle/hot-aisle containment architecture. An N+1 chilled water supply system will operate at elevated temperatures, typically 12°C supply and 18°C return.

For emergency mode (the redundant system for Tier III or Tier IV classification) a suite of electrically driven air-cooled chillers will be at the surface to provide the passive path redundant cooling system.

However in normal service the chilled water circuit will transfer the rejected IT heat via plate heat-exchangers to the chilled water pipe-work of the adiabatic coolers or, in standby mode, the surface mounted electric air-cooled chillers. In the first instance the ventilation inlet shafts will be provided with fans to push a total of 450m³/second (12 changes per hour) through the segregated mine roadways to the adiabatic coolers in the underground voids. The coolers will consume less water than the average rainfall to chill the chilled water circuit and will remove 10MW_{thermal} without using a compressor cycle to achieve continuous (seasonally independent) free-cooling. The exhaust air carrying the moisture laden heat will exit the mine through the ventilation exhaust shafts.

The efficient resilient power system

The Spring Park facility is uniquely positioned close to the internodal point between two separate parts of the UK National Grid (400kV/275kV) system (South-West & South-East England) and is connected to the internodal substation, via the local 11kV/33kV/132kV local distribution network in a truly diverse and redundant manner to provide upto 114MVA of power, of which 40MVA is 2N, the remainder will be N+1. The SQ17 facility on the surface has 12MVA allocated, of which the first 2MVA module opens in November 2009. The remaining power capacity is for further surface data centre developments and the ultra-secure underground facilities.

High-efficiency rotary UPS and kinetic energy storage (battery free technology) and associated emergency diesel-generation will be located at the surface to minimise the heat rejection underground and to facilitate ease of maintenance etc. The UPS will be Low Voltage, 400V, to facilitate maintenance but the power distribution system will be at Medium Voltage, 11kV, so as to minimise transmission losses.

The UPS system will comprise multiple sets in N+1 redundant architecture. The modularity and scalability of a parallel group will ensure the highest possible load factor and, therefore, highest possible operating efficiency.

To transfer the power underground with minimal losses, the voltage will be stepped up to Medium Voltage, e.g. 11kV, and stepped down to 400V, at the vaults. Diverse routes will be taken for the active and passive paths to the districts below.

As in the (surface) SQ17 Data Centre the ‘underground’ UPS system will be high efficiency, battery-free and not require plant-room air-conditioning – all with the design parameter of minimum losses and lowest PUE.

The lowest PUE in the world with the highest specification?

Based on the cooling architecture described above, the losses in the fans and pumps associated with the adiabatic process are the only mechanical cooling losses in normal operation. Because the free-cooling via the adiabatic coolers is available continuously, the PUE will be constant year-round. With variable-speed drives applied to all fans and pumps the efficiency at partial loads will be optimised. In this way the PUE will be lower than 1.2

without recourse to fresh-air cooling with its associated wide temperature and humidity fluctuations.

Taking the holistic view described above and the unique attributes of the Spring Park site, and leveraging 170 years of private and public sector investment, the facility at Spring Park will now become one of the world's leading data centre campuses – secure, available and truly sustainable.



Western entrance to Box Tunnel, Corsham, Wiltshire - built by Isambard Kingdom Brunel and opened in 1841

Presented by:

Dr. Ian Bitterlin, CTO of Prism Power Limited, and

Pip Squire, Engineering Director of Ark Continuity Limited

at the Government ICT Goes Green 09 Conference, QEII Conference Centre, London

Tuesday 15th September 2009