Australian Government

Geoscience Australia

Geoscience Australia Building, Canberra

Geothermal Air Conditioning: 10 Year Review

Executive Summary

The Geoscience Australia building located in Symonston, ACT utilises one of the largest Ground Source Heat Pump (GSHP) systems in the southern hemisphere. The GSHP system utilises the very stable nature of the earth's temperature at depth which remains at around 17 degrees throughout the year. This is a valuable resource – especially when considering the large range in temperatures experienced in Canberra from lows of minus 4° through to highs above 35°. This constant temperature is used as a source of heating or cooling depending on the requirements of the building.

The system is based on a series of 210 geothermal heat pumps throughout the general office area of the building, which carry water through loops of pipe buried in 352 bore holes each 100 metres deep, to exchange heat with the earth.

The system is the largest of its type in Australia and the cost model developed at design projected energy savings of over $1 M over the anticipated 25 year life of the plant.

With the building having now been in operation for 10 years, it is an opportune time to revisit original design assumptions and decisions.

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About Geoscience Australia

Within the portfolio of Industry, Tourism and Resources, Geoscience Australia plays a critical role by producing first-class geoscientific information and knowledge. This can enable the government and the community to make informed decisions about the exploration of resources, the management of the environment, the safety of critical infrastructure and the resultant wellbeing of all Australians.

Original Design Development & Research

As part of the original design preparation, Bassett Consulting Engineers provided a report following site inspections in the USA to investigate Geothermal Heat Pump Systems. This report dated December 1994 provided insight into the emerging heat pump systems being used in commercial buildings. The data gathered from the trip was to provide information on existing systems so that options could be considered as part of the building design.

Site inspections covered installations in Texas, Oklahoma, Indianapolis and California. Installations across these states were supplied by various manufacturers and were installed in various buildings including schools, office buildings and medical centres. Various configurations were also inspected including horizontal, vertical and pond type ground loops.

The key findings from the Bassett report related to the following:

- Many water-to-air heat pumps being installed in many states
- Great flexibility through multiple units providing conditioned air only where needed.
- Reduction in waste energy through elimination of re-heat
- No cooling tower maintenance and no associated risks
- Limited static fan pressure which will influence duct and filter design (as well as precluding laboratory areas from GSHP)
- Location of units should not be the ceiling space as was often the case in the installations shown. Floor mounting was shown to be more maintenance friendly.
- The use of de-superheaters for domestic hot water heating was not an option due to low temperature of the superheat and inherent legionella risk. (Note: Superheat refers to the high temperature introduced to the refrigerant in the compression cycle – heat that must be rejected via a condensing system and can be used to provide heating input into other systems).
- Most GSHP systems only employed minimum outside air due to the investment required to install outside air economy duct work has a diminished return on investment given the high Co-efficient Of Performance (COP) of these types of systems.

Some other interesting findings included:

- The Sheraton Hotel in Los Angeles employed a water-to-air heat pump system which utilised a cooling tower for heat rejection. 170 units were installed in guest rooms with no other heating – the mild winters did not cause the water loop to freeze during cooler weather. Maintenance was found to be around 3 – 4 compressors per year (2.4% of install base) plus other typical minor maintenance.
- The World Savings and Loan Assoc. in Los Angeles experienced a replacement rate of around 15 compressors out of 450 each year (3.3% of install base). A drain pan monitoring system was also found to be useful.

Following this report, a detailed life cycle costing report was provided by Bassett Consulting engineers in August 1995. This report took into account of the following information:

- The proposed building design which had been starting to take shape;
- Results of energy inputs/outputs calculated by Enersonics;
- 2 x 100m on-site drill samples;
- Computer based calculations from University of Oklahoma's ground loop sizing program; and
- The latest increases in costs for locating the geothermal equipment as savings from being able to relocate the small amount of laboratory central plant to the roof.

The net result of the life cycle costing report showed a 25 year saving of $936,219 based on net present value when compared with a traditional central plant system.

Installed Geothermal System Operation

Fig.1: Typical Geothermal Unit

The building air conditioning system incorporates 210 packaged water source heat pump units and uses a vertical loop geothermal field as a heat sink.

The geothermal field comprises 352, 100m deep bores into which a flow and return loop of water pipe is routed. These holes and their loops are grouped into sets of eight and are connected in reverse return configuration via horizontal, larger diameter, flow and return pipes to the headers in the geothermal plant room. This means that there are 44 pairs of pipes connecting the plant room to the geothermal field.

Each flow and return header has 11 pipes connected to it so that there are four sets of flow and return headers in the plant room, each with its own associated primary geothermal pump. A fifth pump provides manual standby capability for any of the four main pumps.

Fig.2: Header System

The Ground Loop Heat Exchanger is based on the following Parameters:-

- Maximum Water Temp Entering Ground Loop - 35.5°C over 25 years.
- Fluid Type - Pure Water
- Average Density Rock
- Undisturbed Ground Temp 18.2°C
- Bore Hole Spacing 4.5 m.
- Future Spare Capacity 10%

In operation, each primary pump circulates water from the primary header, to its associated flow header, through the 11 flow pipes, the 88 vertical loops, the 11 return pipes and the return header back to the primary header.

Effectively, there are four separate geothermal fields, each with its own pumps. The fields are brought into operation sequentially in accordance with the schedule below. The order in which each pump comes on is determined by the control system and is adjusted regularly.

Secondary Loop Return Water Temp (°C)	**No of Operating Primary Pumps**
<4	4
4-5	3
5-6	2
6-8	1
8-18	-
18-22	1
22-27	2
27-33	3
>33	4

The selected water flow rate through the geothermal units typically is at the highest figure recommended in the manufacturer's data for each unit. These flow rates are around double the minimum allowable flow rates but do contribute to a slightly better unit coefficient of performance. At full load, the overall energy consumption of the unit and pump combination is slightly less at the highest flow but at low load, this relationship reverses and the overall energy consumption is higher at the highest flow rates. This is because at low loads, the pump power is a more significant relative to total power requirements.

A few calculations done on a model ATV028 unit (the most common with around 45 installed) indicate that at full load the pump power is around 25% of total power and at 25% load, the pump power is around 40% of total power. This is borne out by the load profile of the geothermal system shown below:

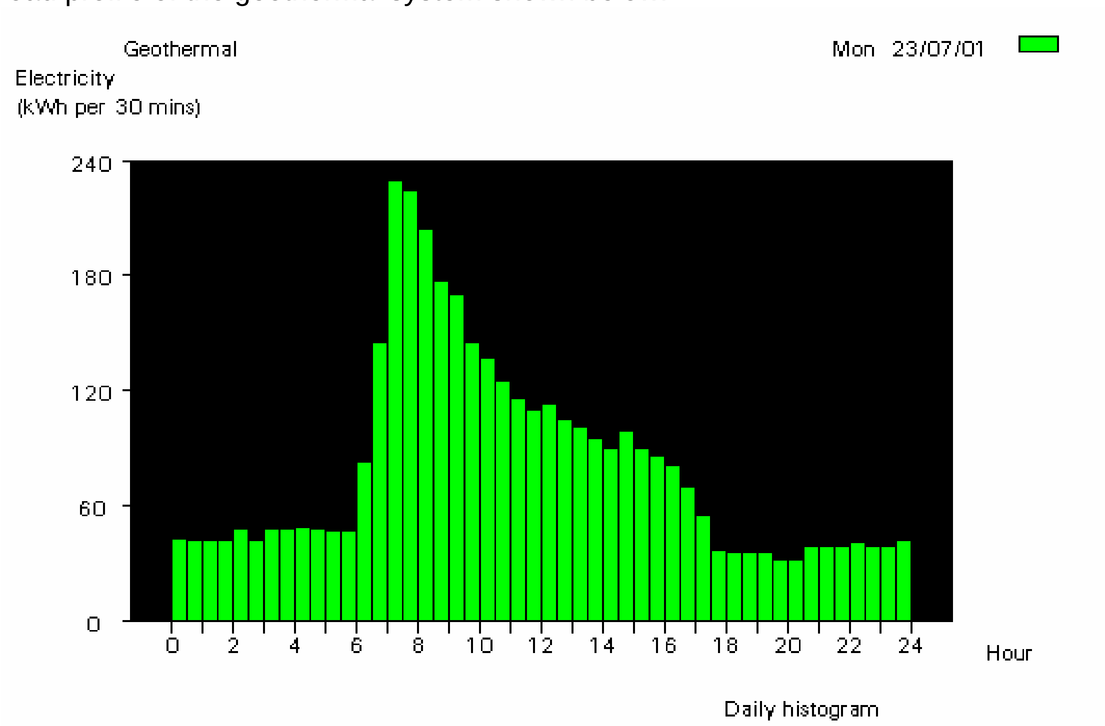

Fig.3: Example daily load

This shows a minimum demand of around 90kW, which represents the demand of the pumps plus maybe one or two units rising to around 470kW at start-up when most units would be operating near full load and then dropping to around 180kW at the end of the day when most units are operating at low load.

Maintenance

Scheduled maintenance is performed via the site's comprehensive Facilities Management (Building Services) contract provider Skilled Group. Routine maintenance predominantly includes the following:

- 1 Monthly: Water quality check and treatment if required
- 3 monthly: Filters inspected/cleaned
- 6 monthly: Controls checked for correct operation

Given the age of system, 2 compressor breakdowns per year are expected at the site representing a failure rate of around 1%.

Other than compressor failures, the units need very little maintenance other than occasional rectification of leaks at the units during the change of season.

As the ground loop is utilised for heat rejection, there is no need to utilise cooling towers or air cooled condensers. This further reduces energy and maintenance related expenses as well as the risks associated with cooling towers.

Benchmark Performance

The Geoscience Australia Building incorporates a number of Ecological Sustainable Development (ESD) design features. With its large footprint and specific operational requirements including laboratories and special storage areas, it is difficult to provide a definitive comparison of building performance. As no 'like for like' comparison is available, the typical energy performance of a selection of buildings within the ACT have been used to give some typical energy consumption figures.

The selected comparison buildings are all of an "office/administration" type function whereas the Geoscience Australia office space **also** includes the following:

- Public education and display areas;
- Open layout and project areas;
- Foyer and internal garden space and voids;
- High intensity 'IT' areas such as the Australian Tsunami Warning System (24/7 operation), server rooms and graphics labs

Benchmark Data	Geoscience Australia
Typical Annual Electricity Use (MWh) – mechanical plant only (no light and power)	1,800 MWh PA
Typical Annual Gas Use (GJ) - mechanical only (no light and power)	6,200 GJ PA
Floor area (GA office space)	30,700m^2
Energy Intensity: Local Benchmark MJ Per Square Meter	**440 - 500 MJ/m^2**
Energy Intensity: MJ Per Square Meter	**413 MJ/m^2 (~15% less than comparison)**

Indicative Savings:
A saving of 15% would equate to approximately $27,000 PA in electricity savings and $13,000 PA in gas savings. Thus, the indicated savings above represent energy cost savings of approximately **$40,000 PA.**

Over the past ten years, this represents a cumulative energy cost saving of around $400,000. In future years, this annual cost saving <u>will grow</u> with energy costs set to increase by up to 30 – 40% over coming years. In effect, the geothermal heat pump system provides some mitigation of the risks associated with these cost increases.

These figures do not include added cost savings derived from cooling tower maintenance and monitoring as well as traditional chiller plant servicing.

Ongoing Performance and Review

Geoscience Australia energy performance is constantly reviewed and further improvements to performance of the geothermal system is expected with work being undertaken in the following areas:

- The Building Controls Management System (BCMS) supported by Honeywell is being upgraded with completion due by February 2008. This includes software upgrade and replacement of controls and sensors for all geothermal heat pumps, set point adjustments for seasonal change including function for local temperature controls, trending and reporting capabilities. Interface between the geothermal system and Honeywell controls will be supported by Bacnet logic;
- Ongoing energy reviews include geothermal pump circulation flow rates and energy use. Consulting engineers engaged to review performance, loads and air balances to optimise performance.

Conclusion

When comparing energy performance in the annual ‘Energy Use in the Australian Government Operations’ reports, the GA Building has maintained energy performance and targets that would normally be contributed to a general office administration building. This is significant given the requirements to provide additional fresh air to laboratories and 24/7 temperature control to special storage areas. This can be contributed to the geothermal system and the other Ecologically Sustainable Development design principles used in the building.

Moving forward, there is scope for additional system improvements. These are possible predominantly with regard to the pumping arrangement as this represents the largest ‘controllable’ component of the geothermal system.

Further Information

The following web pages provide further information on Geoscience Australia and geothermal energy:

www.ga.gov.au
(Geoscience Australia Home Page)

www.ga.gov.au/about/building/
(GA building design features)

www.ga.gov.au/minerals/research/national/geothermal/index.jsp
(GA Scientific research program on geothermal energy)

www.geoexchange.com.au
(geothermal system installations – GA Building Contractor)

Footnote

Geoscience Australia has in place an Energy and Environmental Management System (EMS) Plan and Policy. Tour Andover Controls (TAC) is engaged on a consultancy service as part of the Comprehensive Facilities Management contract to provide energy management services in support of the plan. This includes live data analysis and energy use monitoring, exception reporting, monthly energy consumption reports, annual energy reporting for Commonwealth Agencies (OSCAR), bi-annual energy audits to AS/NZS 3598:2000 and EMS implementation and support. For further information on these services, please contact Peter Dickinson on (02) 6202 2100, peter.dickinson@tac.som or www.tac.com .

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