informa-TECH

GazMétro DATECH GROUP

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Unveiling the results of the geothermal natural gas demonstration project

It's now an alternative. The new absorption heat pump technology is added to the options of customers who want to increase their buildings' energy performance. The results of the demonstration project are available after more than one year of continuous measurement. This is a promising technology, because it is the only one that can provide heating temperatures higher than 45°C (115°F) by adapting it to a geothermal system. It is also the only technology that can operate as air source heat pump (ASHP) from outdoor temperatures as low as -29°C.

The versatility of natural gas, which achieves 95% heating efficiency levels by condensing water vapour from its own combustion, is thus reaching new highs. Its efficiency now achieves levels ranging from 120% to 135%.

A successful demonstration

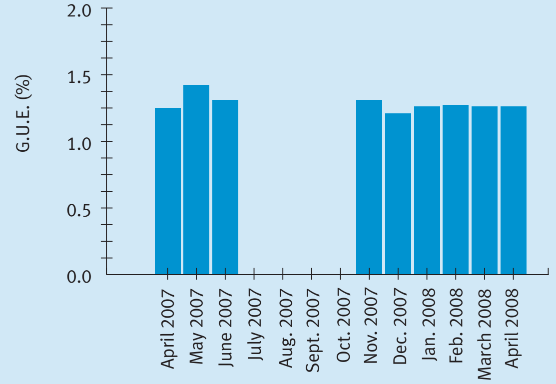
In spring 2005, Gaz Métro's DATECH Group undertook a commercial demonstration of the performance and reliability of natural-gas ground source heat pump, a first in North America. The Montréal engineering firm CIMA+ integrated a natural gas geothermal option into its plans and specifications for renovation of one of the multiple buildings of the Benny Farm housing complex. Unlike the complex's other buildings, the 24 units belonging to *Société d'habitation et de développement de Montréal* (SHDM) accepted this option. The costs of this implementation amounted to $140,000 for five vertical wells 168 metres deep and three Robur heat pumps with a single-pump capacity of 38 kW (130 MBh) for heating and 18 kW (5 tonnes) for air conditioning.

The building's original cast iron hot water system was kept for greater comfort and due to the fact that it can handle lower temperatures efficiently. Startup of the units was in March 2007, and after one year of measurement, the results meet the reliability and efficiency expectations.

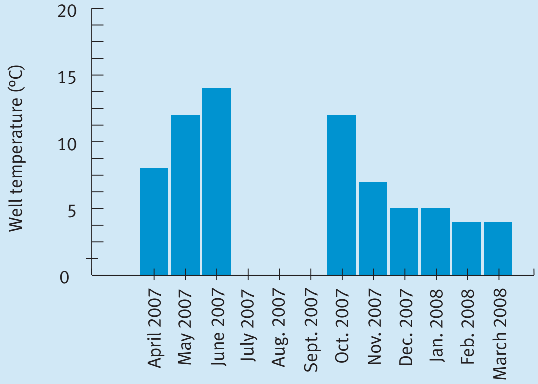
An excerpt of the efficiency results measured on a monthly basis by the Natural Gas Technologies Centre (NGTC) is also presented below. They corroborate the manufacturer's specifications (G.U.E. is similar to COP). Note that as in any geothermal project, efficiency varies according to the temperature of the well (evaporator) and the heating temperatures (condenser). The physical accuracy of the possibility of obtaining a temperature of 60°C (140°F) on the evaporator could have been verified.

EXCERPTS FROM THE RESULTS OF THE *NATURAL GAS TECHNOLOGIES CENTRE (NGTC)* DEMONSTRATION PROJECT – 24 SHDM HOUSING UNITS

ANNUAL EFFICIENCY OF ABSORPTION PUMPS (G.U.E. = gas utilization efficiency)



WELL TEMPERATURE EVOLUTION (Return of the propylene-glycol mixture)



SCENARIO 1: THEORETICAL COMPARISON OF DIFFERENT OPTIONS RELATED TO A PROJECT WITH HOT WATER-HEATED RADIANT FLOORS
(evaporator input T° = 5°C; condenser output T° = 46°C (115 °F)

Basic volume for a standard installation Building heated with conventional equipments (75% efficiency) – Reference volume 52,800 m^3/year or $28,456/year (2000 Gj/year) at 20% ECD		
Condensing boiler	**Geothermal with electricity**	**Geothermal with natural gas**
→ 100% gas heating → With boiler at 94% efficiency → Predicted volume of 42,130 m^3/year @ 54.6¢/m^3 → **= $23,003/year** → (1596 Gj)	→ Electrical GSHP (COP of 2.5) → With auxiliary gas heating and ECD 94% eff. → 120,050 kWh/year for 90% heating of the envelope @ 7¢/kWh 11,795 m^3/year @ 59¢/m^3 (ECD + 10% heating of the envelope) → **= $15,363/year** → (879 Gj)	→ Natural gas GSHP → No auxiliary heating → 29,333 m^3/year @ 55.7¢/m^3 → **=$16,338/year** annual saving vs. reference volume $12,118 or 888 Gj → (1111 Gj/year)

Comparative application scenarios

Two theoretical scenarios of the heating needs of these 24 housing units were simulated for comparison: a hot water-heated radiant floor system (low temperature) and a cast iron heat transfer system (medium temperature). For each scenario, three technologies were evaluated on the basis of a standard heating installation to define the energy cost of the different possibilities.

Scenario 1

Considering that geothermal electricity requires auxiliary backup (70%/30% rule), we find that for the same new commercial building, geothermal natural gas would not necessitate auxiliary heating for use of the same ground sink, while the energy costs of heating would be totally comparable.

Scenario 2

On the other hand, for higher temperatures, as in the case of a medium or high-temperature water system, it is not adequate to use geothermal electricity, because the compression technologies do not produce the desired performance with Canada's soil temperatures.

An efficient technology for modernization of existing buildings

Most of the time, the hot water heating systems of existing buildings do not operate at low temperatures as in the case of radiant floors. The design temperatures range from 50°C (120°F) to 90°C (200°F) at input. Yet the feed water temperature of geothermal electrical heat pump is rarely higher than 45°C (115°F). Above this temperature, the life cycle of geothermal compressors decreases very rapidly. In fact, at a feed hot water temperature of more than 45°C (115°F) and a well temperature of 1°C (35°F), it is possible to end up with unpleasant surprises, because very high mechanical stresses are exerted on the compressor. This is not the case with natural gas absorption technology.

In cooling modes, the absorption heat pump is less efficient than the electric heat pump. Therefore, within the context of modernization of an existing building's heating system, the option of dehumidifying only the air make- up during hot weather could prove to be an inexpensive and efficient air conditioning solution, by storing energy in the soil in summer for reuse in winter geothermal heating. Furthermore, within the context of the

SCENARIO 2: THEORETICAL COMPARISON OF DIFFERENT OPTIONS RELATED TO A PROJECT WITH A CAST IRON HEAT TRANSFER SYSTEM (DEMO PROJECT)
(evaporator input T° = 5°C ; condenser output T° = 60°C (140°F)*

Basic volume for a standard installation Building heated with conventional equipments (75% efficiency) – Reference volume 52,800 m^3/year (2000 Gj/year) at 20% ECD		
Condensing boiler	**Geothermal with electricity**	**Geothermal with natural gas**
→ 100% gas heating → With boiler at 90% efficiency → Predicted volume of 44,000m^3/year @ 54.6¢/m^3 → **= $24,024/year** → (1667 Gj)	→ Electrical GSHP (COP of 2.5) INACCESSIBLE FOR THESE TEMPERATURES	→ Natural gas GSHP → No auxiliary heating (123%) → 32,195 m^3/year @ 55.7¢/m^3 → **=$17,932/year** annual saving vs. reference volume $10,524 or 780 Gj → (1282 Gj/year)

* Note that the measured average temperature of the building's heating loop was 120°F but that theoretically it could be 140°F.

ADVANTAGES OF NATURAL GAS GSHP	ADVANTAGES OF NATURAL GAS ASHP
→ Energy "partially" renewable (substantial reduction of the usual consumption); → Constant soil temperature vs. ambient air temperature for the heat pumps; → Annual efficiency ranging from 120% to 130%; → Lower installation costs in drilling than compression technology; → Feed water temperatures ranging from 37°C to 60°C (100°F to 140°F)	→ The air/water absorption heat pump can operate up to outdoor temperatures of -29°C (CSA certified); → The annual efficiency is more than 105% without any auxiliary heating necessary; → No drilling necessary (use of heat from the ambient air), so the investments are clearly lower; → Feed water temperatures ranging from 37°C to 60°C (100°F to 140°F)

right energy in the right place, there is good reason to believe that air conditioning can be accomplished with electrical technology while heating can be achieved by natural gas absorption heat pump technology, all through geothermal wells common to both technologies. (*see* Magazines *Gaz Québec,* Autumn 2007, and *La Maîtrise de l'Énergie,* March 2008).

Moreover, given that its COP is lower, it was estimated that geothermal natural gas necessitates a ground heat exchanger 40% shorter than conventional geothermal, for identical heating needs. This can turn out to be a compromise solution for well drilling investments.

In conclusion, it is interesting to note that units can also be installed both indoors and outdoors, but this time using air instead of soil as the heat sink. These units are natural gas ASHP (see above image). Since absorption heat pumps do not have a mechanical compressor, they can withstand extreme temperatures and thus can operate at temperatures as low as -29°C. This contrasts with the usual air-to-air heat pumps, which operate down to -5°C. These air/water units can also heat water to 60°C (140°F).

Finally, water-to-water absorption heat pumps can be used very efficiently in any industrial or commercial heat recovery project.

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A systemic approach that shows results

Accounting for each dollar spent on energy and where it goes is essential for any business. It is also important to know the bases of comparison of these costs and the reasons for the variances when they appear. MT&R, or Energy Monitoring, Targeting and Reporting, is a high-performance management method that helps optimize energy use.

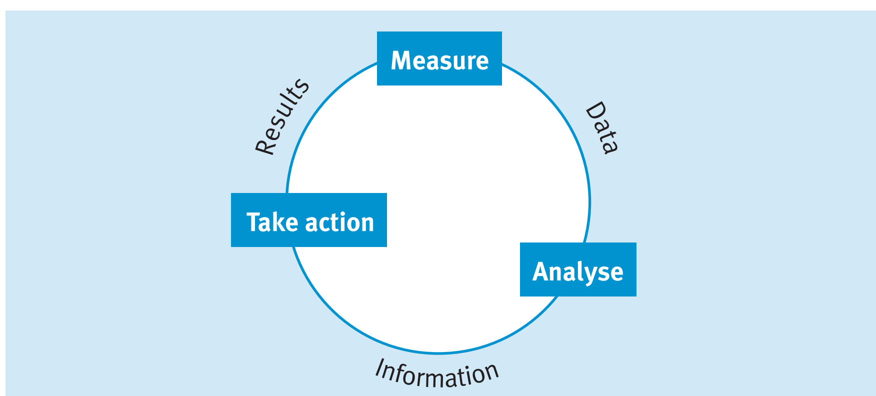

Figure 1. MT&R cycle

What is MT&R?

MT&R allows a historical analysis of the energy performance of a building or a process. This technique is increasingly applied in North America. With the data collected the manager can establish objectives to reduce consumption, control energy performance and thus establish a budget or future actions.

Implementing an active close monitoring system for everything related to a company's energy consumption can achieve savings ranging from 5% to 15%.

MT&R should be perceived as a cycle of measuring, analyzing and taking action, as illustrated in Figure 1.

The steps to follow

To ensure a successful MT&R process and derive the maximum benefits from it, here are the crucial steps to follow:

- → Measure energy consumption and collect data on the different variables over time according to a predetermined frequency;

- Establish an energy performance model. This means defining the functional relationship between energy and the independent variables;
- Produce a historical analysis of energy performance and use the curve for future needs. CUSUM (Cumulative Sum of Differences) is a functional analysis that makes it possible to establish this curve and is defined in this article;
- Define the reduction objectives and establish an action plan to ensure the goals are achieved;
- Monitor the results.

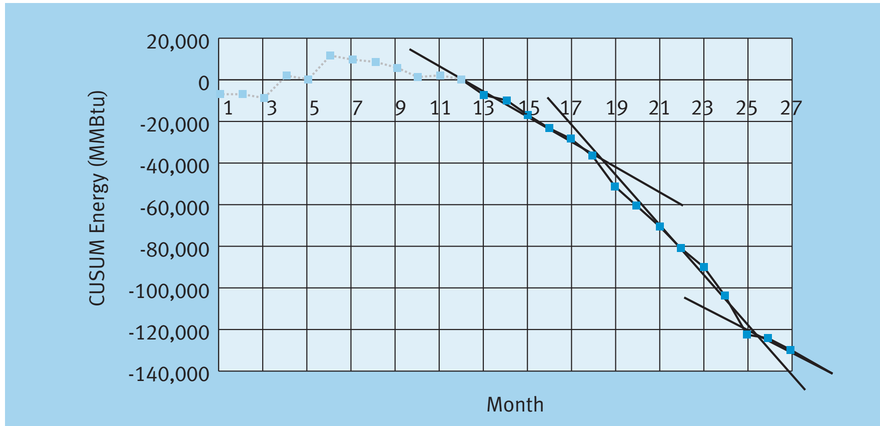

Figure 2. CUSUM trends

CUSUM: effective modeling

Within the context of implementation of MT&R, CUSUM allows rigorous tracking of the variances between the energy performance model defined initially and the actual consumption measured, according to a predetermined frequency. This will shed light on the variances so that managers can orient their actions.

To establish an effective CUSUM, it is essential to use a unit of measure of physical energy (MJ, m^3, litre, kWh, etc.) because it is fixed in time. Although the objective is to reduce costs, dollars are not a reliable unit to compare energy consumption over time.

The data of a food processing plant will illustrate CUSUM. The manager of this facility first identified a variable: production in pounds. The first step is to define an energy performance model. As shown in the above graph, the first 12 months of consumption and production of a 27-month history serve as a performance model. During this period, no energy saving measure had been implemented. The equation of the baseline model translates into y = 2.0078x + 64,966. The slope, 2.0078, represents the incremental in energy consumption per pound produced. The constant 64,966 represents the energy consumption independent of production. Energy consumption and production readings were taken monthly throughout the process.

CUSUM is constructed from the sum of the variances between the energy performance model and the data collected monthly. CUSUM thus is the sum of all the differences for each period. The CUSUM graph is plotted according to the periods analyzed, as illustrated in Figure 2.

This graph reveals changes in energy performance at every point where there was a change in slope. Thus, a downward trending line indicates savings and an upward trending indicates an increase in the consumption rate. For example, starting in the thirteenth month, energy saving measures were established, since the slope of the curve changes. In all, for the period analyzed, about 130,000 MM Btu were saved in relation to what the consumption would have been according to the baseline model.

Based on the different readings of the CUSUM graph, the manager adapts his MT&R and ensures that his energy saving objectives are achieved. This energy management technique in a building or a process is a constantly evolving but extremely profitable cycle. In summary, to optimize energy performance, it is first essential to know the actual status of energy consumption by means of a tool such as CUSUM and then define the objectives and actions to take in order to improve the situation and then validate achievement of the objectives.

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Reference:
Guide to Energy Management, Fifth Edition, Barney L. Capehart, Wayne C. Turner and William J. Kennedy, Chapter 1. Note: This article is an adaptation of an excerpt from section 1.7 written by Doug Tripp, P. Eng., Executive Director, Canadian Institute for Energy Training, and Stephen Dixon, President, TdS Dixon Inc.

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