#4364

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Department of Education and Science
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MONERGY '86

Use of heat pumps in rural schools

Introduction

Rural schools away from gas main networks often have a limited choice of fuel. A heat pump can offer an attractive and cost effective alternative in such cases. This Broadsheet describes two schools where heat pumps have been successfully installed.

Heat pumps work on a similar principle to the domestic refrigerator. In a refrigerator, heat is absorbed from the space to be cooled and ejected to the outside air. In the case of a heat pump, heat is absorbed from the atmosphere (or other suitable source eg river water) and transferred to the space to be heated. The ratio of the heat output to the electrical input (to drive the compressor) is known as the coefficient of performance (COP). Heat pumps normally operate with a COP between 2 and 3 when averaged over the year. Thus a heat pump operating with a COP of 2 is producing 2 kW of heating energy for every 1 kW of electrical energy it consumes.

Appleton Wiske, North Yorkshire

This replacement school was built in 1983. The school was designed to accommodate 90 children aged 5–11 years in three teaching spaces, with adjoining cloakrooms and lavatories, all grouped around the hall. The rest of the accommodation comprises a servery, staffroom and other ancillary rooms and storage. The total floor area is 490m².

The building shell was designed specifically for low energy consumption. It has a low wall to floor ratio and is covered with a low pitched roof, which houses the heat pumps and ductwork (Figure 1). Glazing has been kept to an acceptable minimum; all external doors have draught lobbies. Construction is generally traditional with an emphasis on minimum external maintenance. The building is well insulated. External walls are of brick/blockwork, having a 75 mm cavity with 25 mm slab insulation bonded to the inner skin. This gives an overall U-value for the wall of 0.37 W/m²°K. Windows are double glazed. The school has a slate roof on rafters and purlins with a suspended ceiling, providing easy access to the roof space for servicing and adjusting the air distribution system. Suspended ceilings are insulated with 100 mm removable insulation slabs, giving an overall U-value for the roof of 0.37 W/m²°K. The solid floor has insulation between the structural slab and finishing screed; where a hardwood floor finish is used there is insulation between the supporting battens. The floor has an overall U-value of 0.42W/m²°K.

The school is heated by warm air which is distributed through insulated ductwork in the roof space (Figure 2). Three electrically driven air-to-air heat pumps are used to warm the air, zoned as follows:

- west zone – classrooms and toilets
- east zone – classrooms and administration areas
- north zone – hall and kitchen

The heat pumps have a COP of 2.5 and combined output of 35kW. Each pump has a 7.5kW auxiliary electric heater arranged in 3 banks of 2.5kW. These are switched on by a step controller when the outside temperature drops below the preset limit. An additional 6kW emergency electric heater is also installed in the same casing. It is manually switched on if the heat pump fails. Auxiliary heaters and the emergency heaters together give a 100% standby capacity. Domestic hot water is provided by individual electric water heaters to each area.

When running normally the system provides 25% fresh air, which meets the DES minimum requirement of 30m³/hr/pupil for mechanically ventilated systems. At start-up the fresh air dampers are held closed until the required space temperature has been achieved. During the summer the heat pump cycle can be reversed to provide comfort cooling when necessary.

	Appleton Wiske School	DES requirement
energy design value		
kW/m² PEU	133	158
annual energy consumption values		
kWh/m² PEU	214	310

Table 1. Appleton Wiske School – energy values

The total cost of the school was within the DES cost guideline. The school also meets the DES Design Note 17[1] energy requirements. Table 1 shows the energy design value (EDV) and annual energy consumption values (AECV) and compares them with the DES targets.

The system has operated well since installation, without any major maintenance or operational problems. The staff are happy with the conditions in the school. The system has also been economic to run. Table 2 compares the running cost and the capital cost of the heating system at this school with another new comparable primary school in the same LEA which has a conventional heating system with an oil fired boiler plant. Both the schools were completed in 1983.

	Appleton Wiske School	Amotherby School
capital cost of heating system (1983 prices)	£54/m²	£70/m²
annual heating cost	£4.78/m²	£4.35/m²

Table 2. Comparison of capital and running costs

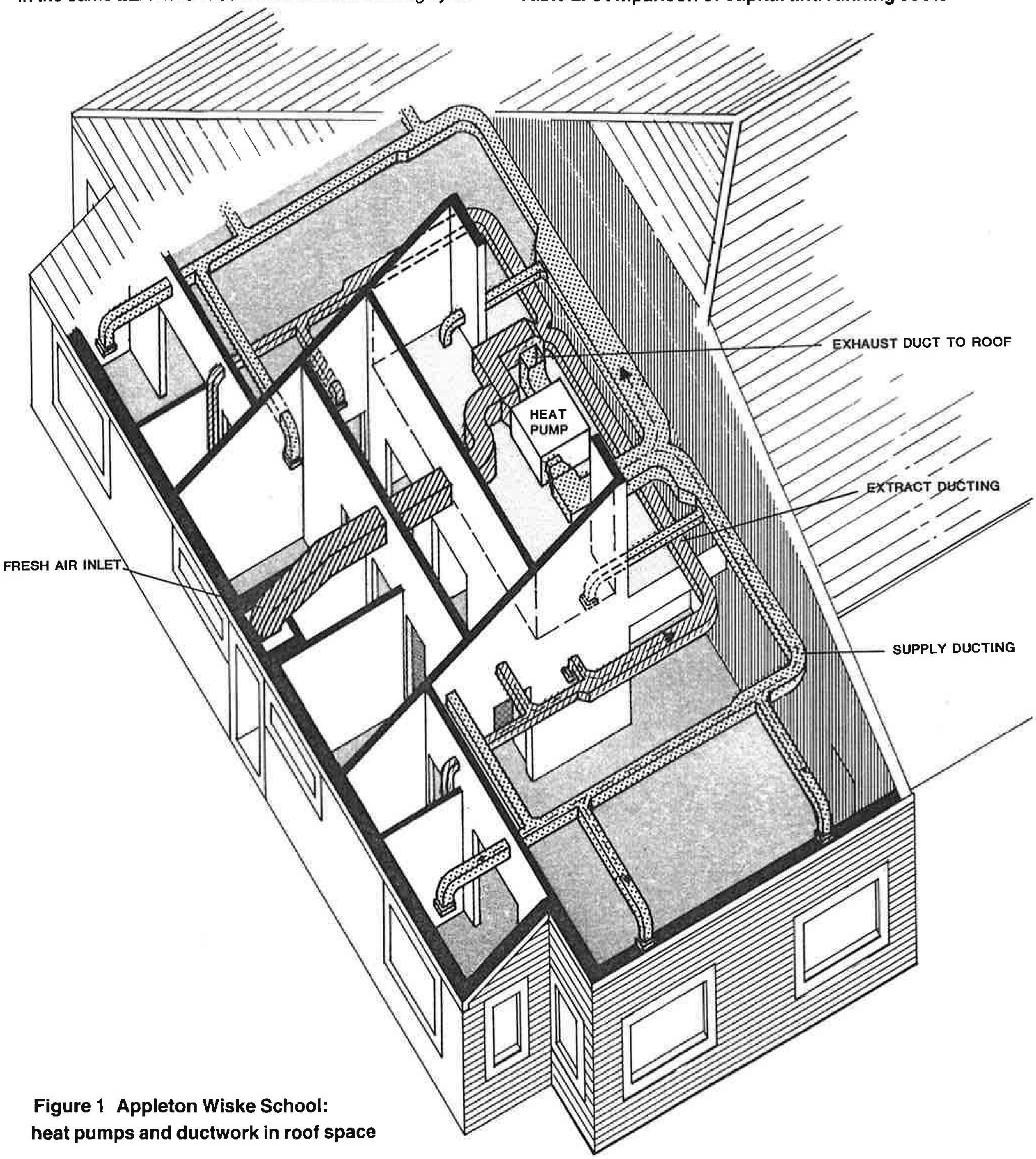

Figure 1 Appleton Wiske School: heat pumps and ductwork in roof space

[1]*Guidelines for environmental design and fuel conservation in educational buildings.* Design Note 17, DES, 1981

The annual running cost for the Appleton Wiske school is slightly higher because the heat pumps are regularly used in summer to provide cooling.

Bradworthy Primary School, Devon

This small village school dates back to 1872. A $293m^2$ extension, added in 1985, houses four classrooms and a shared resources area. The internal walls in the old school were removed and the building is now used as a hall. The school can accommodate 104 pupils and has a total area of $453m^2$. Figure 3 shows the plan of the school with its heating system.

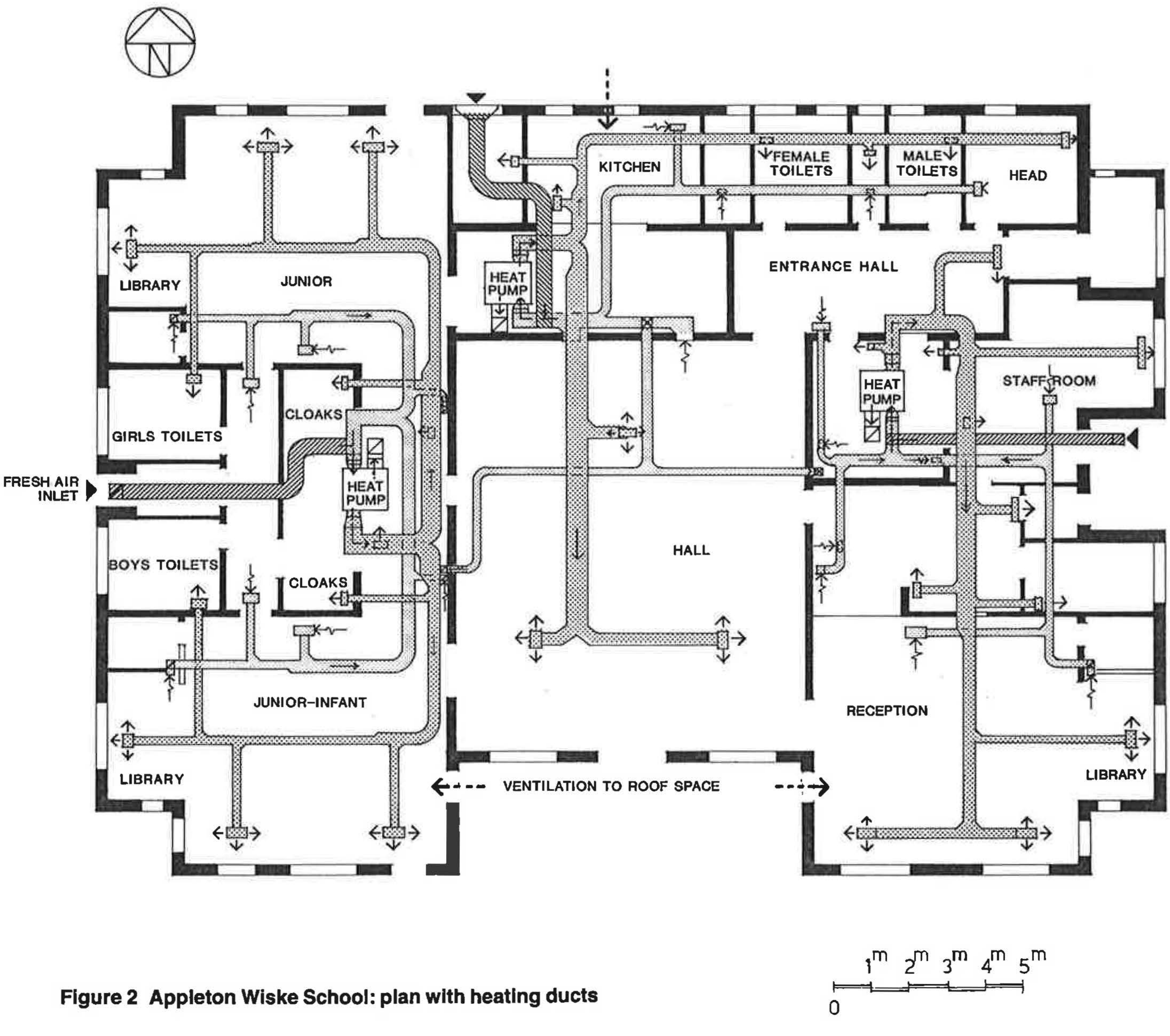

Figure 2 Appleton Wiske School: plan with heating ducts

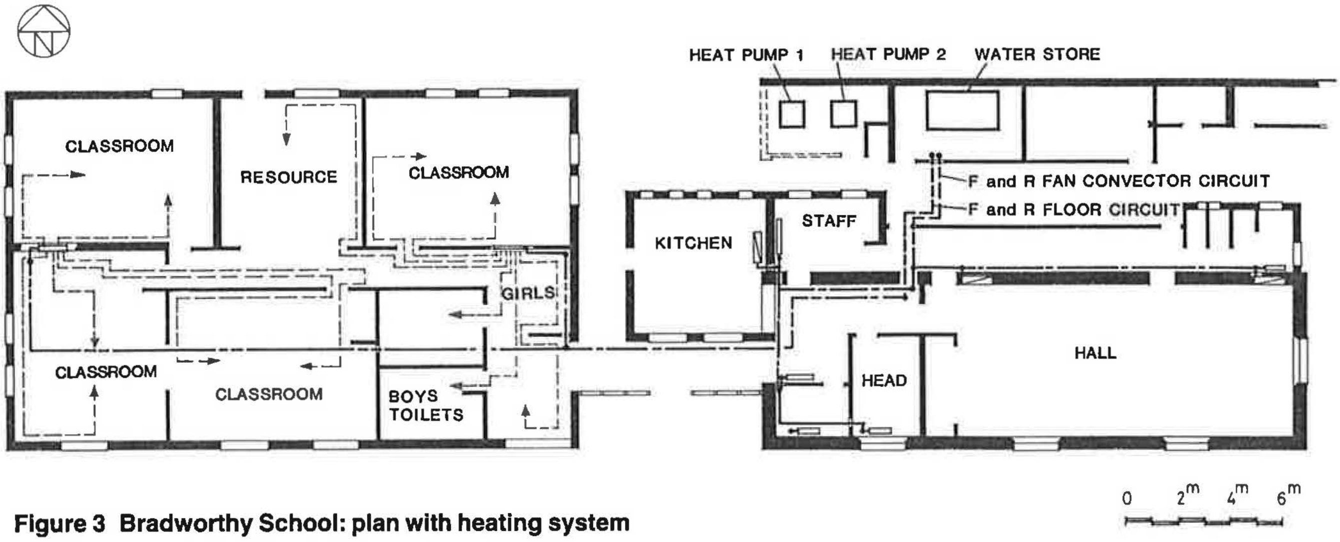

Figure 3 Bradworthy School: plan with heating system

In the new building the external walls consist of 150mm insulating blocks on the inside and 100mm dense concrete blocks on the outside, with a 50mm cavity between, giving a U-value of 0.5W/m²°K. The tiled roof has 80mm of glass fibre insulation over timber joists giving a U-value of 0.35W/m²°K. The old building has 600mm thick solid stone walls rendered on the inside; the U-value is estimated to be about 1.5W/m²°K. The EDV and the AECV were well within the DES targets (see Table 3).

	Bradworthy School	DES requirement
energy design value		
kW/m² PEU	**71**	**158**
annual energy consumption values		
kWh/m² PEU	**180**	**310**

Table 3. Bradworthy School – energy values

The school has a low temperature hot water (LTHW) heating system. The system comprises two 15 kW air to water heat pumps and a water store. There are two heating zones: the new extension and the old building.

The new building has underfloor heating with flexible polypropolene pipes laid on insulation over the concrete slab. After testing, the pipes were covered with special screed. The underfloor heating is controlled by a compensator and radiators have thermostatic radiator valves. The old building is heated by fan convectors, on a constant temperature circuit. Domestic hot water is provided by electric heaters.

Under normal conditions the heat pumps run at night, to take advantage of the off peak tariff, and heat up the water in the water store. The store is a 6.5m³ glass fibre tank, with 100mm of U-foam insulation on the outside. The heat pumps switch off when the store is fully charged. When the optimiser calls for heating in the morning, hot water is pumped from the store into the heating circuits. The store is sized to meet the heating requirements for a normal working day. If for some reason (eg colder weather) the store is discharged before the end of the day, then it is bypassed and the heat pumps come on and supply the heating circuits directly. The store has three 6 kW emergency electric immersion heaters built into it, so if the heat pumps fail to start, the store can be charged up by the immersion heaters at night. Figure 4 shows a schematic diagram of the system.

The building cost of the new extension was within the DES guidelines. Table 4 compares the capital and running costs of the heat pump installation with estimates for an oil fired LTHW heating system. The capital cost of heat pump installation is about 7% less — largely due to the omission of a boiler house, chimney and storage tank for oil. The running cost of the heat pump installation is also less.

	electric heat pump system	oil fired LTHW system
capital cost	£27,384	£29,320
annual running costs	£ 1,844	£ 2,137

Table 4. Comparison of capital and running costs (at August 1984 prices): electric heat pump system and oil fired LTHW system

This system has now been in use for one heating season — the winter of 1985-86. There were some teething problems in the first season of operation and in February 1986 when conditions were extremely cold over a long period the heat pumps failed to maintain the temperature in the school at an acceptable level. This was because the heat pumps were spending a large part of their operating time in the defrost cycle. However, and significantly, the performance of the heat pumps indicated that with the COP of 2.8 the system would provide a satisfactory level of heating down to an external temperature of 3°C. To remedy the poor performance below this temperature the authority is installing three electric flow heaters in the heating flow, as indicated at Figure 4 at an approximate cost of £600. These heaters are rated at 6 kW each and will come into operation if the flow temperature is not high enough. As a result the future running costs might be slightly higher than originally estimated but still lower than those of the alternative system.

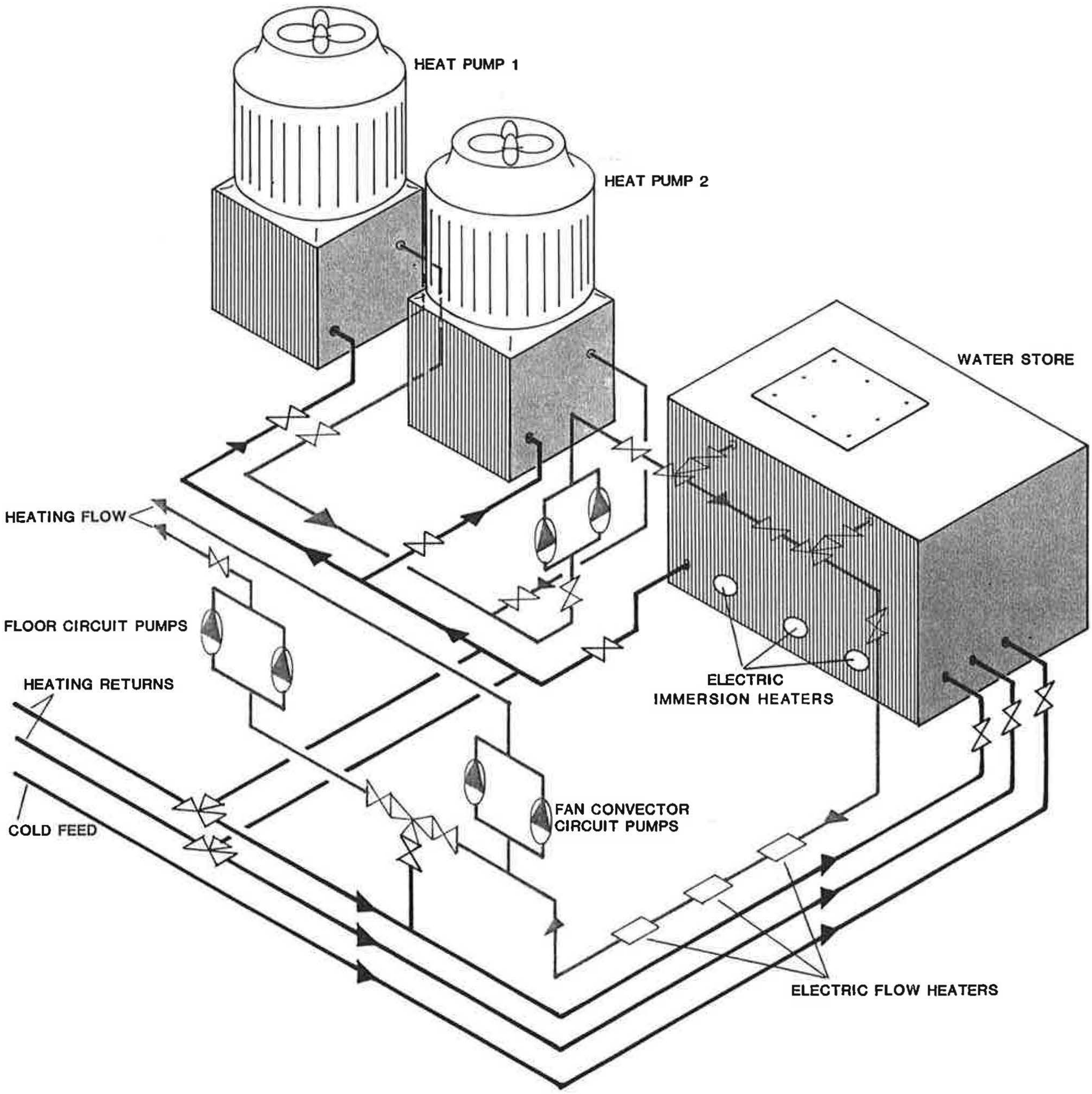

Figure 4 Bradworthy School: schematic diagram of heating system