HEAT RECOVERY REFRIGERATION

IN

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ABSTRACT

Increased energy costs initiated an investigation into refrigeration heat recovery as one conservation alternative available for reducing water heating costs on farm dairies. A theoretical energy balance was conducted, from which the potential of recovering refrigeration condenser heat was estimated at up to 60% of the water heating energy requirements.

Preliminary tests with heat exchangers lead to the use of a tube-in-tube, counter flow, heat exchanger with fins on the refrigerant side, and cores on the water side, to improve the heat transfer characteristics. The exchanger, designed to provide 300 litres of 60°C water from a 2.25 kW refrigeration system cooling 2000 litres of milk per day, had an area of 0.84 m^2, and an overall thermal conductance of 100 $W.m^{-2}.°C^{-1}$. This heat exchanger was inserted between the compressor and condenser of the refrigeration plant and tested with two condenser systems (air and water), four condenser pressures (6.5 bar, 7.5 bar, 10 bar and 12 bar), two milk inlet temperatures (23°C and 18°C), and two milk final temperatures (4°C and 7°C). In addition, tests on receiver pressure and suction superheat were performed to determine overall system performance.

Increasing condenser pressure increased cooling times from 2 hours 32 minutes to 3 hours 17 minutes, after the completion of the 1200 litre morning milking (thus failing to comply with the 3 hour cooling regulation at high condenser pressures.) Also, C.O.P. decreased from 3.05 to 2.35 for the water cooled condenser system (2.70 to 2.00 for the air cooled condenser system due to fan power consumption). Gross heat recovery rose from 4.2 $kWh.day^{-1}.m^{-3}$ to 8.1 $kWh.day^{-1}.m^{-3}$ for the water cooled system, giving water outlet temperatures of 45°C to 64°C as condenser pressure rose. The corresponding ranges for air cooled condensers were 3.8 $kWh.day^{-1}.m^{-3}$ to 6.6 $kWh.day^{-1}.m^{-3}$, and 38°C to 55°C. Changing milk inlet and final temperatures gave a proportional change in cooling times and total heat recovery, but had no effect on C.O.P. or heat recovery rates. Suction superheating increased total heat recovery by 15%, and water outlet temperatures by 9%.

Increases in gross heat recovery with increasing condenser pressure were partially offset by additional compressor power, and yielded nett heat recoveries of 4.0 $kWh.day^{-1}.m^{-3}$ to 6.0 $kWh.day^{-1}.m^{-3}$ for water cooled, and 3.6 $kWh.day^{-1}.m^{-3}$ to 4.3 $kWh.day^{-1}.m^{-3}$ for air cooled, condenser systems.

The maximum gross and nett heat recoveries (at 12 bar condenser pressure) were applied to the energy requirements of a monitored 220 cow town supply dairy. This analysis showed that the gross heat recovery was 51% of the water heating requirements, but the nett heat recovery dropped to 17% of the total heating and refrigeration demand. Based on current electricity and equipment prices, it is estimated that the payback period for this level of recovery would be 16-17 years. Changing the electricity pricing structure, to reflect up to a 1:3 differential in favour of water heating power costs, results in the 6.5 bar condenser pressure giving optimum results, but the nett returns are significantly lower than those reported.

The potential for improved savings is greater from larger capacity systems as the capital investment is not proportionally increased with an increase in scale.

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