



# Retrofit cogeneration system at milk processing plant

## Summary

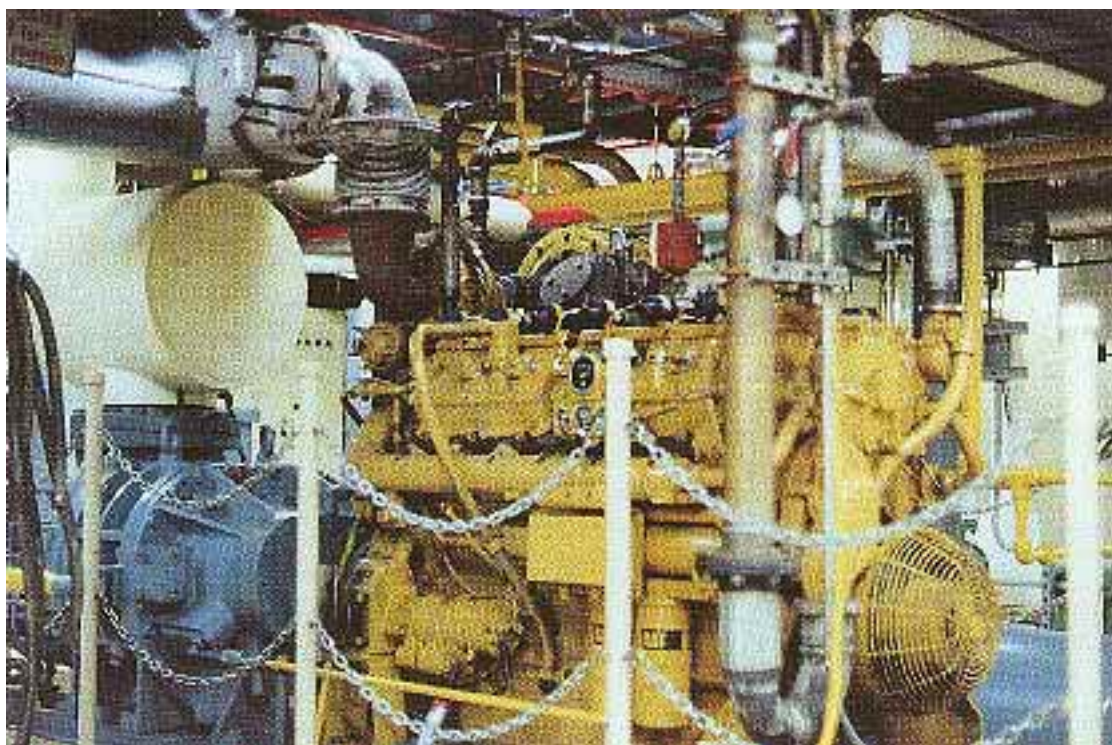
*By retrofitting an integrated cogeneration system, the Honeywell Farms dairy processing facility achieved energy and cost-saving goals. Innovative elements employed to reach these goals included: using cogeneration concepts for refrigeration prime*

*movers; waste energy recovery using absorption refrigeration for subcooling; and exhaust heat recovery for steam generation. This project was the ASHRAE "First Place" award winner in Category IV: "Industrial Facilities or Processes" for an existing facility in 1993.*

## Highlights

- Electric energy demand reduced more than 50%
- Improved plant COP by 6% at all loads

*View of 600 H.P. Cat natural gas engine and Frick rotary screw ammonia compressor at Honeywell Farms.*



## Aim of the Project

Honeywell Farms Dairy owners were concerned about rising electrical energy costs and sought ways to improve energy efficiency. They wished to augment an effective energy management programme with additional energy conservation efforts. Data collection and analysis was undertaken with the following goals:

- investigate the use of cogeneration technology for refrigeration applications;
- evaluate utilising waste heat recovery for subcooling;
- reduce the energy costs associated with the refrigeration plant while expanding processing capacity.

## The Principle

This project includes three elements which have proven successful in operation:

- the use of cogeneration concepts for refrigeration prime movers;
- waste energy recovery using absorption refrigeration for subcooling to boost the coefficient of performance

(COP) of the refrigeration plant;

- exhaust heat recovery for steam generation.

In a subcooling system, as used in this project, chilled water from an absorption chiller can be used to cool liquid refrigerant of the main refrigeration system far below its saturation temperature. An additional refrigeration effect equivalent to the enthalpy difference to the saturation temperature reduction is obtained by this process. This added refrigeration capacity is provided without additional work input to the compressor. Since the cooling capacity of the system is increased without a corresponding increase in energy consumption, the COP is improved. Allowing for a reasonable temperature approach as heat is transferred between the refrigerant and chilled water in the subcooling heat exchanger, energy savings of 8 to 10% can be expected if the thermal load remains constant. In this arrangement, the added capacity is equal to the capacity of the absorption machine.

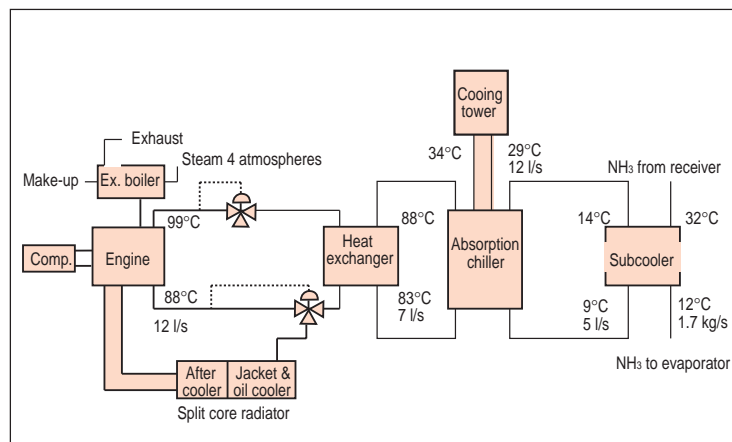
## The Situation

A natural gas-engine-driven compressor was configured into an existing building by remodelling the equipment room and relocating some existing equipment. The system consists of a 450 kW (600 hp) turbocharged, twelve cylinder natural gas engine directly coupled to a screw type ammonia compressor. Heat from the engine jacket is used to produce chilled water in three 35 kW (10 tonnes) lithium bromide absorption refrigeration units. The chilled water is circulated through a heat exchanger to subcool liquid ammonia refrigerant after it leaves the refrigeration system condenser. The heat rejected from the absorption refrigeration units is rejected to an atmospheric cooling tower. Heat is furthermore recovered from the engine exhaust using a waste-heat steam generator rated at 147 kW (500,000 BTU/hr). The steam is produced at a pressure of 4.5 atmospheres (65 psi) and is utilised for process steam (see Figure 1).

The engine, compressor and heat recovery equipment combine to form a highly efficient cogeneration plant. Very high fuel efficiency is obtained and substantial savings are achieved when compared with the separate conventional steam generators and electric powered refrigeration systems used previously.

This plant was installed parallel to the existing refrigeration plant. The existing plant consisted of seven electrically driven reciprocating ammonia compressors of 264 kW

Figure 1: Schematic of the engine subcooling system.



Fuel source	All-electric plant	Engine-compressor based plant without subcooling	Engine-compressor based plant with subcooling
Electricity (kWh)	1,853,462	655,633	178,298
Natural gas (MJ)	251,400	2,156,800	2,362,000

Table 1: Annual energy consumption for the refrigeration plant.

(75 tonnes) capacity each and two back-up compressors of equivalent capacity. None of this equipment was removed from service. The cogeneration plant's waste heat boiler was connected to the plant steam header in parallel with existing packaged, gas-fired boilers. When the engine is operating, the gas-fired boilers are shut down. A by-pass valve was installed around the waste heat boiler to divert exhaust flow in the event that the waste heat boiler was unavailable.

Normally, the absorption units are operated to remove heat from the engine jacket. In the event that the absorption units are not operated, engine cooling can be rejected to an engine radiator on the roof of the building. Thus, the plant has a maximum amount of efficiency and flexibility.

The engine/compressor system is now used for base load operation. When it is used in conjunction with the subcooling system the engine/compressor cogeneration system has been able to provide more than 80% of the required cooling capacity. This performance included downtime accumulated as the result of unexpected power failures, planned maintenance activities and operation performances.

### The Organisation

The Honeywell Farms Dairy milk processing plant is one of the largest in the New York City area. The plant processes milk which arrives daily by tank trucks from milk producing areas in New York. The milk is pasteurised and bottled at this 8,361 m<sup>2</sup> (90,000 ft<sup>2</sup>) facility located in the Jamaica section of Queens. The plant

started as a small operation over 50 years ago and has grown since then to become the largest independent milk processor in the Long Island area.

### Economics

The total installation costs for the engine-compressor based refrigeration plant with subcooling were USD 519,540. Compared with an all-electric plant the additional costs were USD 339,540.

Estimates of annual energy consumption and costs were developed using a model-based approach. The costs include all appropriate taxes, demand charge, fuel adjustments, a monetary credit for the waste heat recovered as steam from the engine exhaust, and maintenance costs.

These configurations include an all electric plant, an engine-compressor based plant without subcooling and an engine-compressor based plant with subcooling. A summary of the energy consumption for the refrigeration plant is shown in Table 1, and an estimated simple payback based on energy savings is shown in Table 2.

Table 2: Estimated simple payback based on energy savings.

Option	Project costs (USD)		Annual cost (USD)		Payback (yrs)
	Total	Incremental cost	Total	Incremental savings	
All electric plant	180,000	0	317,400	0	N/A
Subcooling engine-compressor	519,540	339,540	227,000	90,400	3.8
Non-subcooling engine-compressor	385,220	205,220	202,150	115,250	1.8
Subcooling increment	0	134,320	0	24,850	5.4

The gas consumption and cost data given in the tables was reduced to account for the steam generated from the engine exhaust. It was assumed the recovered heat displaced natural gas that would otherwise be consumed in an on-site boiler at an 85% combustion efficiency. These natural gas energies reflect the baseload energies which would be provided by a base plant natural gas fired boiler. The engine-compressor based plant replaced these energies with waste heat recovered from the engine.

Table 2 presents the simple payback for the subcooling and non-subcooling engine compressor systems in comparison to the all-electric plant based on capital costs and annual operating expenditures (energy purchases and maintenance).

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\* IEA: International Energy Agency  
 OECD: Organisation for Economic Co-operation and Development

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This is achieved, in part, through a programme of energy technology and R&D collaboration currently within the framework of 35 Implementing Agreements, containing a total of more than 60 separate collaboration projects.

**The Scheme**

CADET functions as the IEA Centre for Analysis and Dissemination of Demonstrated Energy Technologies. Currently, the Energy Efficiency programme is active in 15 member countries.

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