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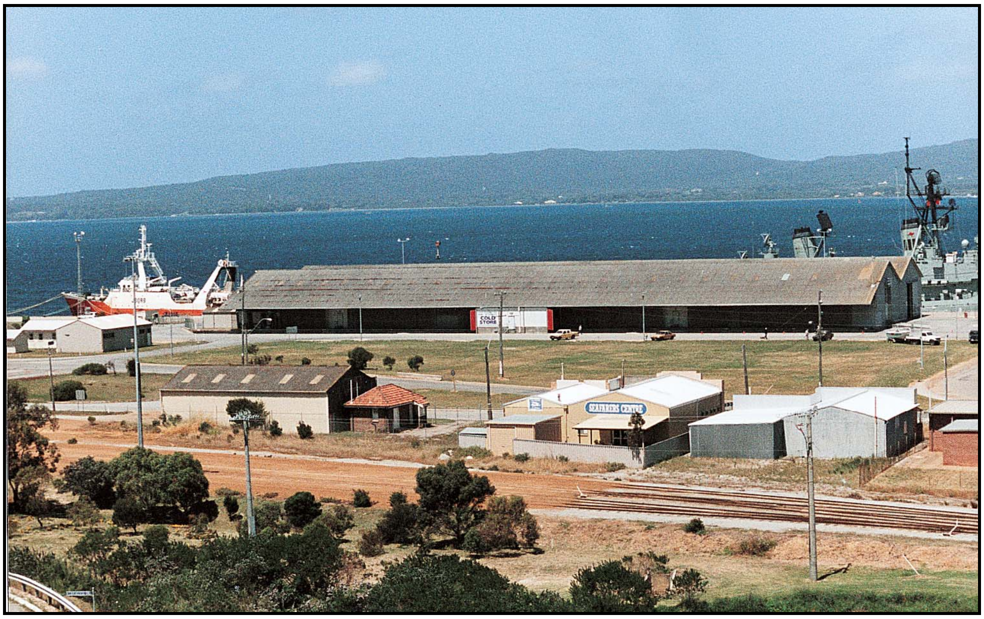

Transit shed building houses the cold store facility. Products stored in freezers are loaded directly on ships for interstate transport and international export.

An Efficient Cold Store Facility

By C.A. Lommers
Member ASHRAE

Albany Port Authority's new cold store facility has two large freezer compartments separated by a common ante-room and a loading dock area accommodating two dock shelters. The total development was constructed inside an existing transit shed on the wharf in Albany, Western Australia. The location provided additional challenges since it's 450 km (280 miles) from a major city.

The refrigeration system design was specially developed to be at the forefront of technology, using an environment-friendly system design and a refrigerant which satisfied the requirements of the Montreal Protocol.

Selecting a Refrigerant

The requirements established by the Montreal Protocol and its subsequent revisions, prevents the importation and production of chlorofluorocarbon (CFC) refrigerants in Australia from Jan. 1, 1996 forward. Hydrochlorofluorocarbon (HCFC) refrigerants are subject to control measures which limit their availability, and will be phased out totally by Jan. 1, 2030.

Hydrofluorcarbons (HFCs) and ammonia refrigerants are not included in the Montreal Protocol, as they are considered ozone benign alternatives, having a zero ozone depletion potential. An analysis of both refrigerant options indicated that the additional capital expenditure incurred by an ammonia refrigeration system could not be justified by the potential energy savings.

The facility, which is considered a major industry development in the region, required the selection of an efficient, and long-term HFC refrigerant for the low-temperature refrigeration system. HFC refrigerant blends available on the market at the time of documentation in July 1994 included R-404A, R-407B and R-507. Refrigerant R-407B was discounted as it has a significant temperature

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About the Author

C.A. (Cees) Lommers is principal of C.A. Lommers & Associates Pty Ltd. in West Perth, Western Australia. He has more than 20 years of experience in the design of refrigeration and mechanical systems. He is active in the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) and is the author of the *CFC Phase Out User Guide*. More than 30,000 copies of the guide have been distributed.

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In-roof attic enclosure provides easy access to major equipment, including air circulation fans, evaporator coils and expansion valves.

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glide, which was considered outside the realm of technical expertise available in Albany, Western Australia.

The energy benefits of a refrigeration system (compressor input power only) using an evaporative condenser in lieu of an air-cooled condenser were calculated to represent approximately 222,000 kWh per annum (or $27,660 per annum at a unit cost of $0.1246 per kWh).

The majority of electric power in Western Australia is generated by coal or gas-fired power stations. The total energy required for the operation of the refrigeration system would therefore have direct impact on global warming of the planet.

The Global Warming Potential of R-507 and R-404A, refrigerants was calculated using the principles of TEWI (Total Equivalent Warming Impact). The comparative, calculated results are shown in *Table 1*. The final refrigerant selected for the project was R-507, which is an azeotropic blend using two pure refrigerants which have an improved performance and a lower TEWI than refrigerant R-404A.

Refrigeration System Design Criteria

The design criteria are summarized in *Table 2*. The external ambient conditions are 30°C dry bulb and 18°C wet bulb. The internal design conditions for freezers A and B are -20°C dry bulb (90% RH), and 7°C (75% RH) for the anteroom.

Refrigeration equipment load calculations, based on the above criteria were carried out by a computer program specifically designed and developed by C.A. Lommers and Associates Pty Ltd. The calculated results are shown in *Table 3*.

Equipment Selection

The system design for the project comprises three circuits, two equal-sized, low-temperature circuits serving the freezer rooms and one circuit serving the anteroom. Each low-temperature circuit comprises two equal-sized reciprocating compressors, a stainless steel evaporative condenser, a liquid receiver, and a float type oil return/equalization system. An equipment heat balance was prepared for each circuit to ensure optimum performance of the equipment selected for the project.

	R507	R404A
TEWI - 20 years:	2,675,290	2,665,979
TEWI - 100 years:	13,376,448	13,329,894
TEWI - 500 years:	66,882,240	66,649,472

Table 1: Global warming potential of two refrigerants.

Existing Structure and Maintenance Access

The existing structure provided a unique opportunity to access equipment via the roof void rather than from the refrigerated space as is the conventional method for maintenance access to equipment.

To capitalize on this feature, it was necessary to design and develop special self-contained attic enclosures, each housing the required equipment to satisfactorily cool each freezer space.

The resulting design incorporated seven attic enclosures, each fitted with two refrigeration coils and six air circulation fans. Four attic units were installed in the larger freezer (freezer A) and three units were installed in the smaller freezer (freezer B). Access to each of these units has been provided directly from the in-roof catwalk system.

All control equipment, valves, etc. are mounted external to the attic enclosure thus providing direct access for service personnel without the need to enter the refrigerated space. Condensate drains within sub-zero rooms/enclosures were kept to a minimum. All refrigeration system components located inside each attic enclosure can be serviced, removed and replaced without having to enter the refrigerated space or move stock.

Anteroom Pressurization and Ventilation

A common problem experienced in cold stores is excessive air infiltration through gaps associated with loading dock ramps/dock levelers and open doors. High infiltration rates to anterooms significantly increase space humidity levels within this transit area, which increase moisture problems in the adjoining freezer room compartments.

The system was provided with an evaporator specifically designed to reduce humidity levels and pressurization of the anteroom space, thereby minimizing the effect of infiltration to the freezers. The assembly is provided with a row split, low velocity evaporator coil, return air plenum, outside air inlet and draw through evaporator fans.

The primary task of the evaporator is to dehumidify the anteroom air in favor of temperature control. The additional benefit of this system is the provision of ventilation and improved air quality control within a transit anteroom type area.

Air Distribution

A conventional refrigeration system design uses underceiling induced draught, or similar evaporators, comprising short case axial or propeller type supply air fans, providing high air movement with unidirectional airflow. The system installed at the Albany Port Authority Cold Stores uses ducted axial flow

Details:	Freezer A:	Freezer B:	Anteroom:
Panel Thicknesses: • Walls & Ceilings: • Floor:	 200 mm 150 mm	 200 mm 150 mm	 75 mm nil
Internal Heat Gains: • People: • Lights: • Equipment:	 4 5.5 kW 2 Forklifts	 4 4.0 kW 2 Forklifts	 6 2.0 kW 2 Forklifts
Doors: • Quantity: • Type: • Size: • Openings per day: • Time open/entry:	 1 Rapid Door 2.4 x 3.0 m 100 5 minutes	 1 Rapid Door 2.4 x 3.0 m 100 5 minutes	 2 Dock shelters 2.4 x 3.0 m 4 45 minutes
Product Load: • Type: • Quantity per day: • Entering Temperature: • Leaving Temperature:	 Meat 60,000 kg -10 -20	 Meat 40,000 kg -10 -20	 nil
Maximum Daily use:	15 hrs	15 hrs	15 hrs
System Operating hrs:	18 hrs daily	18 hrs daily	16 hrs daily
Compartment Footprint Size:	1,100 m^2	785 m^2	197 m^2
Compartment Volume:	6,160 m^3	4,396 m^3	948 m^3

Table 2: Design criteria for cold storage facility.

aerofoil fans located below the ceiling with bellmouth air intakes and discharge ducts, arranged in such a way that a uniform airflow is achieved within the freezer space.

Snap Cooling Facility

As the facility is an accredited QA/QC freezer transit/export store, it was desirable to have provision for snap cooling of products that arrived in a frozen state, but above the acceptable minimum temperature as required by the appropriate regulations.

One of the evaporator/attic enclosures in the smaller freezer (freezer B) was provided with a larger surface area evaporator coil, specifically designed to operate as a conventional system under normal conditions, with the ability of being quickly converted to a temporary snap cooling unit.

The lower temperature sub-cooled air is automatically re-directed to a low level discharge grille, and canvas cloth tunnel stretched over the warm product. This method significantly accelerates the cooling process of the warmer product.

Energy-Saving System Features

• ***Low-energy recirculation fans:*** Air circulation fans used in a refrigeration system can operate up to 24 hours daily (excluding defrost cycle). An effective air distribution system, utilizing an efficient system design can significantly reduce energy consumption and improve temperature control in the refrigerated environment.

Total fan power for a conventional system, serving the cold store would normally absorb 45.6 kWh. The selected system utilizes axial flow aerofoil fans which have an absorbed power of 28.6 kWh. The reduction in power consumption represents a savings of approximately 147,370 kWh per year or $18,362 (37% of the fan power consumption).

• ***Low-energy defrost system:*** The system design incorporates a low-energy hot gas defrost system which utilizes heat rejected from the refrigeration compressors to defrost ice build-up on refrigeration coils. Surplus hot gas returning from the refrigeration coils is returned directly into the evaporative condensers (not in the suction line as is the case for conventional systems), thus avoiding increased compressor energy consumption during a defrost cycle.

• ***Low-energy underfloor heating system:*** Freezer rooms having an operating temperature of approximately -20°C have a potential of freezing moisture below the insulated freezer room floor. It is therefore necessary to heat the floor to maintain a temperature above freezing directly below the floor insulation.

The heat required for the underfloor heating system is recovered from the refrigeration compressors by storing waste heat in an insulated tank. Hot water flow under the floor is regulated in response to underfloor temperature by sensors located directly below the freezer rooms insulated floor. These sensors are monitored and controlled by the central computer system.

• ***Low-energy condensers:*** Compressor heat rejection is achieved via evaporative condensers rather than air-cooled condensers.

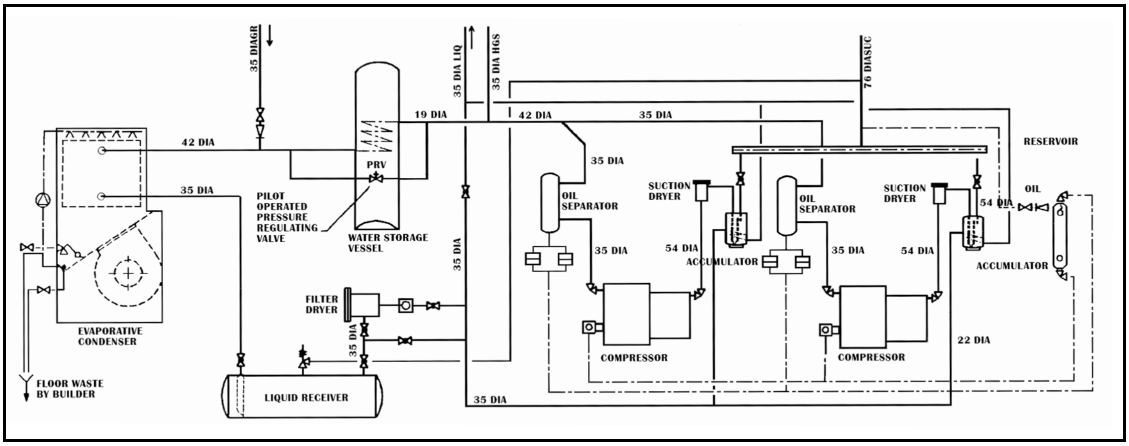
• ***Low-energy air infiltration control:*** Conventional system designs permit external ambient air infiltration to occur during loading and unloading procedures within the refrigerated dock area. The system design for Albany includes a pressurization system which forces air out of the loading dock area rather than permitting it to infiltrate from outside, thus minimizing energy consumption and operating conditions within the refrigerated space.

Computerized Monitoring and Controls

The use of a computerized monitoring and control system enables the control of the facility to be a totally self-contained system. All functions, temperatures and conditions are monitored and recorded every 24 hours. System energy-saving features provided by the computerized control system include:

• ***Sequential operation of components:*** All system components are fully controlled by the computerized control system, switching components in response to sensors and pre-determined control sequences to provide a stable environment within the freezer and anterooms.

• ***Optimized operation of compressors and refrigeration equipment:*** The energy tariff available to the facility operator makes provision for a reduced unit cost for off-peak operation (i.e. between 10 p.m. and 8 a.m. on week days and all



A typical low-temperature circuit.

weekend). The control program for the system optimizes on off-peak operation, by storing surplus cold in product and structure, which is released to the space during the day.

• ***Optimized heat gain through the floor:*** Temperature probes located directly below the insulated freezer room floor monitor and control the adjoining temperature, thus minimizing heat gain and ensuring an above freezing condition is maintained at all times.

• ***Twenty-four hour off-site monitoring facility:*** The computerized monitoring and control system can communicate with off-site equipment via a modem and suitable telephone line.

• ***Twenty-four hour alarm reporting:*** In the event of system failure or malfunction, the computerized control system will convey an alpha-numeric message to display the fault on a designated pager anywhere in Australia.

Energy Consumption

Since the building and its services were commissioned in February/ March 1995, the owners have monitored the total energy consumed by the installation. This monitoring, together with a planned maintenance program designed to improve operating conditions, set points and operational sequences, has resulted in a steady reduction in energy consumption. System control functions were modified during the month of March 1996 to maximize low-cost, off-peak energy, and reduce on-peak energy consumption. The cost of electricity charged by the authorities is $0.054 for off-peak use and $0.175 for on-peak energy consumption.

Energy consumption recorded during the period from Apr. 12, 1995 to May 16, 1995, can be summarized as follows:

Off-Peak Power Use:
1,574.3 kWh per day

On-Peak Power Consumption:
1,099.6 kWh per day

Later records taken during the period from Sept. 6, 1996 to Sept. 15, 1996 indicated a reduced consumption of:

Off-Peak Power Use:
1,416.9 kWh per day

On-Peak Power Consumption:
849.0 kWh per day

In summary the energy consumed by the plant over a period of 12 months, based on 5.4 cents for off-peak and 17.5 cents for on-peak power charges are shown in *Table 4*.

	Freezer A:	Freezer B:	Anteroom:
Individual Room Loads:	106.8 kWR	82.3 kWR	40.8 kWR
Low Temperature Circuit:	189.1 kWR		
Medium Temp. Circuit:			40.8 kWR

Table 3: Equipment load calculations.

	kWh	kWh/m^3	$	%
Conventional air cooled system design	1,345,340	127.45	147,290	100.0
Conventional evaporative condenser system design:	1,123,340	106.42	119,630	81.2
Energy consumption of Albany Cold Store System:	827,050	78.35	82,150	55.8
Energy savings:	*38.5%*	*38.5%*	*44.2%*	*44.2%*
Energy savings achieved by:				
• Evaporative condensers:	222,000	21.03	27,660	18.8
• Fan power savings:	147,370	14.96	18,360	12.4
• Optimized system operation:	148,920	14.11	19,120	13.0

Table 4: Energy consumed by plant over a 12-month period.

Summary

The Albany Port Authority Cold Stores have provided the region with an energy-efficient facility which clearly fulfills the objectives of the Montreal Protocol. ■

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