ENERGY SAVINGS BY WASTE HEAT RECOVERY
FROM REFRIGERATION AND AIR CONDITIONING SYSTEMS
"HOW AND HOW MUCH"

Air conditioning / refrigeration systems are designed to remove heat from interior spaces or products and reject it to the ambient (outside) air. Heat rejection may occur directly to the air, as in the case of most conventional air source units, or to water circulating from a cooling tower. The circulating water eventually rejects the heat to the ambient air in the cooling tower. While this heat is of a "low grade variety," it still represents wasted energy. From an energy conservation standpoint, it would be desirable to reclaim this heat in a usable form. The best and most obvious form of heat recovery is for heating water.

HOW MUCH HEAT IS AVAILABLE ?

Before deciding whether heat recovery makes sense for an application, it is useful to know just how much recoverable heat is available. The total heat available is the heat removed from the space plus the heat of compression. There are four areas in refrigerant systems where heat can be recovered

1. The condenser
2. Superheat in the discharge gas
3. Compressor jacket or oil coolers &
4. Totally enclosed water-cooled motors.

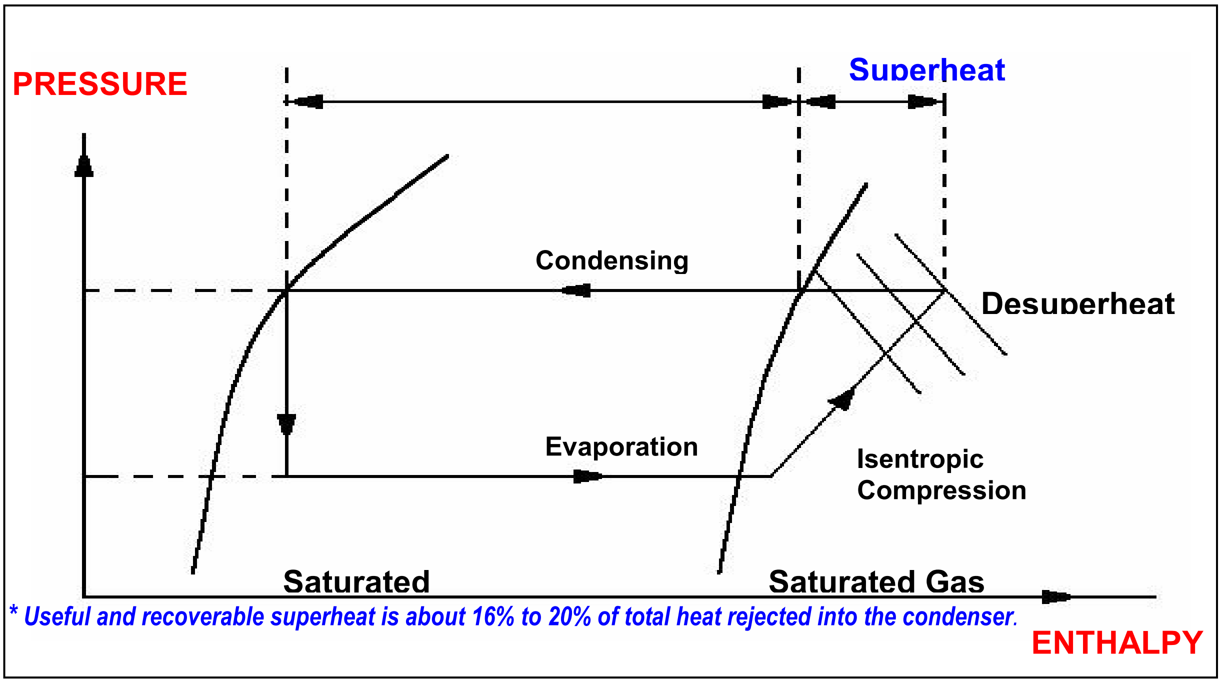

FIGURE- 1 : TYPICAL REFRIGERATION CYCLE

The principle of heat recovery in a refrigeration cycle is shown in fig.(1). It will be seen that the discharge gas coming from the compressor is in a superheated state and some heat can be recovered from this gas by desuperheating it before it enters the condenser. The discharge temperatures in most refrigeration systems are quite high (in the range of 70°C to 100°C). The superheat can be used to heat the water to about 60°C. The amount of heat recovered would be of the order 10 to 15% of the total heat rejected by the condenser. The discharge temperatures of various types of compressors are generally as follows,

Compressor	Discharge Temperature
Screw Compressor (Indirect cooled)	70 → 80 °C
Screw Compressor (Injection cooled)	50 → 60°C
Reciprocating Compressors	85 → 110°C
Boosters (Rotaries & Reciprocating)	75 → 85°C

WASTE HEAT RECOVERY WITH DESUPERHEATER :

A typical schematic arrangement of waste heat recovery (superheat of the refrigerant gas) using the Desuperheater is as follows.

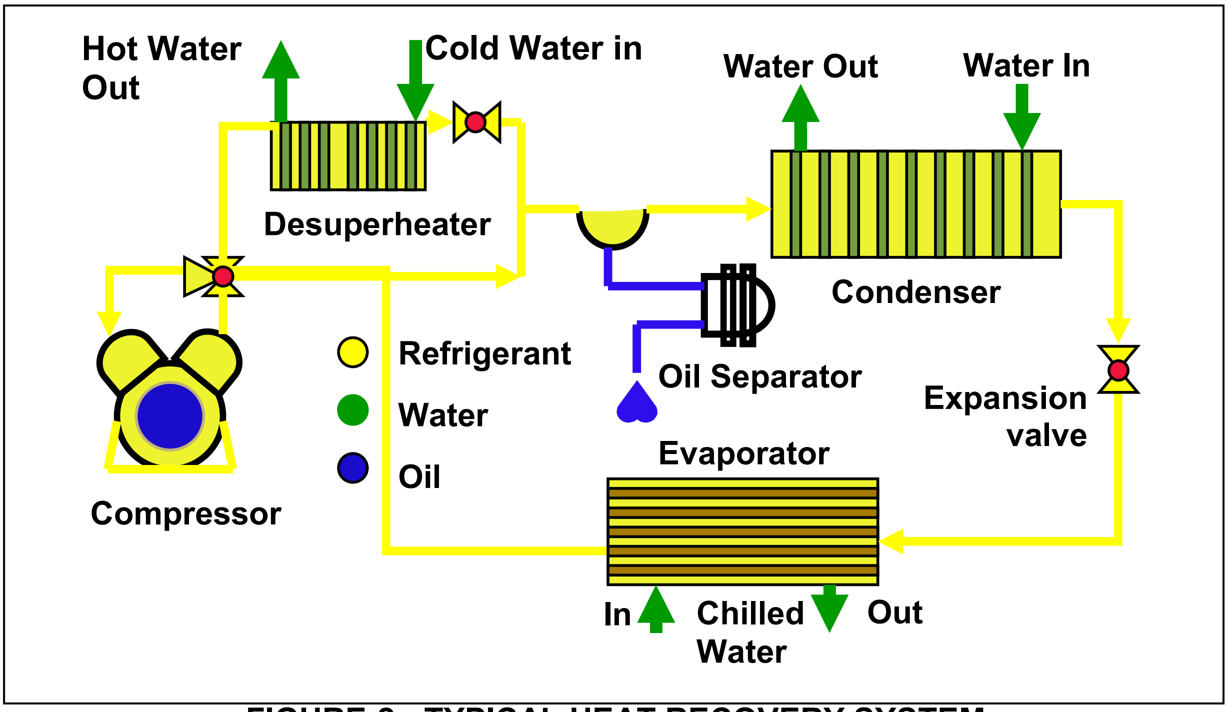

FIGURE-2 : TYPICAL HEAT RECOVERY SYSTEM

The estimates provided represent conservative rules of thumb. However, the amount of available heat that can be turned into useful heat in the form of hot water is limited. A typical heat recovery system is shown in figure. (2) In a typical application the refrigerant line leaving the compressor will be connected to a heat exchanger unit **(Desuperheater**). A return line from the **Desuperheater** will then be attached to the condensing unit. In this way, the hot refrigerant gases will flow from the compressor, through the **Desuperheater**, and then to the condenser. The **Desuperheater** has water circulating through it that is heated by the hot refrigerant gas. The hotter fluid transfers the heat to the colder water circulating through the **Desuperheater**.

AMOUNT OF HEAT THAT CAN BE RECOVERED :

Recoverable Super Heat from Ammonia Refrigeration Systems :

Condensing Temperature °C	Estimated Discharge Temperature °C	Recoverable Heat Kcal/ hr/ kW
43	114	1990
41	104	1800
38	99	1730
35	91	1525
32	86	1450

Recoverable Super Heat From R-22 Systems :

Condensing Temperature °C	Estimated Discharge Temperature °C	Recoverable Heat Kcal/ hr/ kW
46	82	1875
43	77	1700
31	71	1650
35	66	1500

CASE STUDIES :

The case study data for different types of compressors & refrigerants are given below:

Case 1 [R-22]

Compressor with Water Cooled Condenser	**Voltas 5H80**
Capacity	282 kW
Refrigerant	R22
Evaporating Temperature	- 7° C
Condensing Temperature	40° C
Gas Temperature at the inlet to Desuperheater	80° C
Gas Temperature at the outlet of Desuperheater	55° C
Water Temperature at the inlet to Desuperheater	32° C
Water Temperature at the outlet of Desuperheater	55° C
Water Flow Rate	25 lpm

Case 2 [Ammonia]

Compressor with Water Cooled Condenser	**KC- 42**
Capacity	176 kW
Refrigerant	R717 (Ammonia)
Evaporating Temperature	- 35° C
Condensing Temperature	40° C
Gas Temperature at the inlet to Desuperheater	110° C
Gas Temperature at the outlet of Desuperheater	68° C
Water Temperature at the inlet to Desuperheater	30° C
Water Temperature at the outlet of Desuperheater	75° C
Water Flow Rate	6 lpm

Case 3 [R-22]

Compressor with Air Cooled Condenser	**Carrier Semi Hermetic**
Capacity	105 kW
Refrigerant	R22
Evaporating Temperature	- 3° C
Condensing Temperature	45° C
Gas Temperature at the inlet to Desuperheater	90° C
Gas Temperature at the outlet of Desuperheater	55° C
Water Temperature at the inlet to Desuperheater	28° C
Water Temperature at the outlet of Desuperheater	60° C
Water Flow Rate	9. 4 lpm

Case 4 [R-22]

Compressor with Water Cooled Condenser	Trane Screw
Capacity	176 kW
Refrigerant	R22
Evaporating Temperature	- 3° C
Condensing Temperature	42° C
Gas Temperature at the inlet to Desuperheater	72° C
Gas Temperature at the outlet of Desuperheater	48° C
Water Temperature at the inlet to Desuperheater	47° C
Water Temperature at the outlet of Desuperheater	55° C
Water Flow Rate	34. 1 lpm

ADDITIONAL ADVANTAGES OF WASTE HEAT RECOVERY SYSTEMS :

Waste Heat Recovery Systems in industrial Air Conditioning and Refrigeration systems have number of advantages besides the recovery of heat.

1. The operating "condenser" duty is reduced when a Heat Reclaim System is "retrofitted". This reduces the condensing pressure, which in turn reduces the BKW of the compression equipment, and/or reducing the condenser fan horsepower. For new installation it is not recommended that the condenser size be reduced unless the "heat reclaim" requirement coincides with the maximum plant load conditions.

2. Where a Desuperheater is installed, the refrigerant gas temperature inlet to the condensers is reduced, thus reducing the "fouling' tendency of the condenser & thus reducing water treatment requirement.

3. Where a Desuperheater is installed, most of the oil that is normally in Vapor State will condense & a good oil separator can remove it. By removing the oil before it gets to the evaporators, the system efficiency is increased with the possibility that the evaporator pressure can be increased.

   As a "thumb rule" a 1.8°C increases in evaporator temperature decreases energy requirements by approximately 6%. A 3°C increase will decrease the energy requirement by about 11%.

DESIRABLE PROPERTIES OF DESUPERHEATERS :

1. Pressure drop on gas side across inlet and outlet of Desuperheater should not be more than 14KPa.

2. The Desuperheater should be **"Mechanically cleanable"** without interrupting the operation of the refrigeration system.

3. If hot water produced is used as potable water or as preheated water for the boilers, **the design of Desuperheater must ensure that no cross contamination of water and refrigerant gas takes place in the event of tube leakage.**

4. All heat recovery units should be provided with bypass valves that allow the unit to be isolated from the system in case of leaks or maintenance requirements.

Note: The data given in case studies above are actual figures obtained from

M/S Manor Enterprises, Pune from their records. For more details, contact

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