

White Paper

Heat Recovery from Vapor Compression Air Conditioning A Brief Introduction

Michael Guglielmo
Fred Scheideman
Yogesh Magar

Synopsis:

Heat Recovery Units (HRUs) operate with air conditioning and refrigeration systems to harvest excess heat which would otherwise be lost, thereby improving overall energy efficiency and yielding useful heating.

Description:

Vapor compression air conditioning systems service residential, commercial and industrial comfort cooling requirements. A typical vapor compression system consists of four major components viz. compressor, condenser, expansion device and an evaporator and are depicted schematically in Figure 1. Figure 2 is a thermodynamic diagram (pressure/enthalpy) of the process where the numbered points correspond to the numbered points in Figure 1. The operation cycle consists of compressing low pressure vapor refrigerant to a high temperature vapor (superheated condition: process 1-2); condensing the high pressure vapor to high pressure liquid (phase change: process 2-3); expanding high pressure liquid to low pressure super-cooled liquid (process 3-4) and evaporating low pressure liquid to low pressure vapor (phase change: process 4-1). For heat recovery, the process of interest is the compression 1-2 which increases the pressure and temperature of the refrigerant gas; this is known as Heat of Compression.

The heat absorbed from air to be conditioned in process 4-1 is rejected to outside ambient during condensation process 2-3 and is generally a waste heat. The condensation process can be divided in 3 stages viz. desuperheating 2-2a, condensation and sub-cooling.

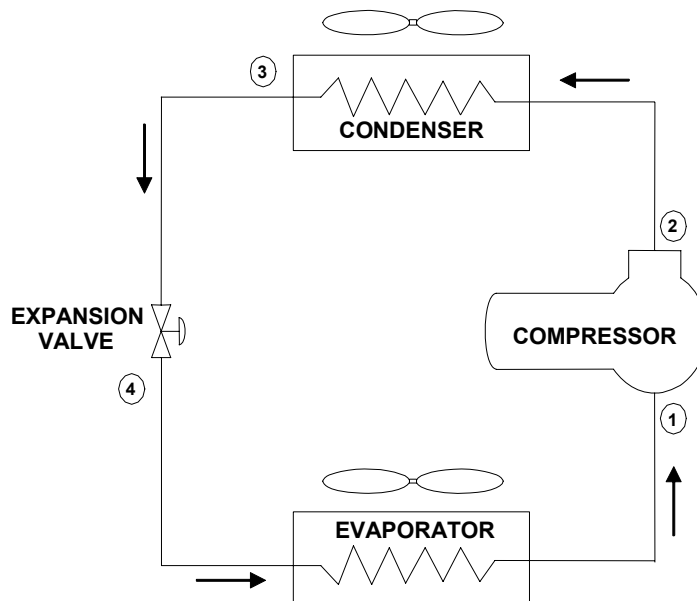
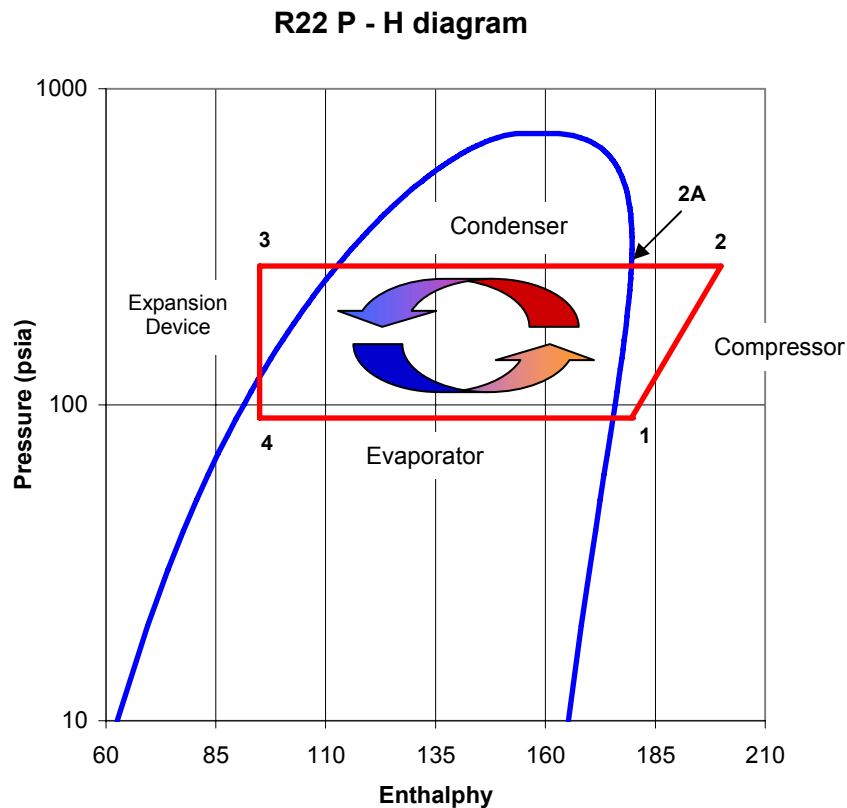
FIGURE 1

FIGURE 2



The compression work (1-2) done on the gas is dependent upon several factors; refrigerant type and the efficiency of the compression process being two of them. This gas is also known as a superheated gas because it exits the compressor at a temperature significantly higher than its saturation temperature. Superheat is proportional to 2-2a in Figure 2.

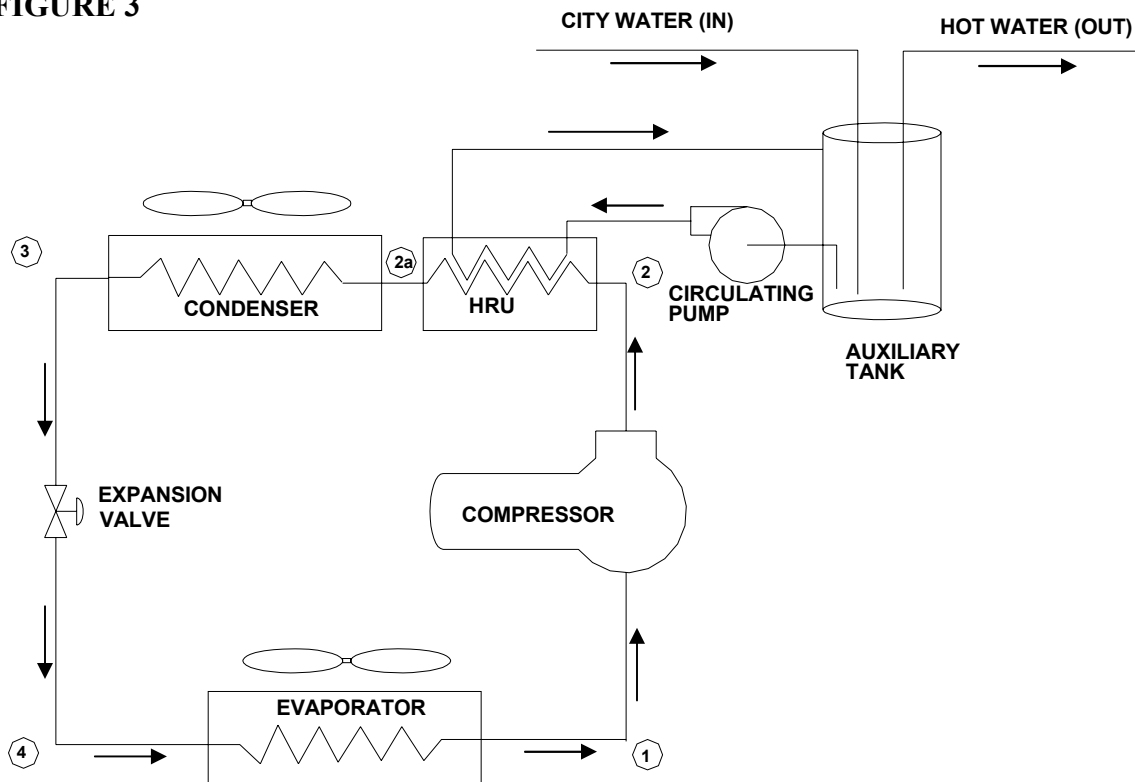
The saturation temperature, by design, is anywhere from ten to thirty degrees above the heat sink fluid temperature, this ensures the heat sink fluid can extract heat from the refrigerant. The superheat can be as much as 100 °F or more above the saturation temperature. This so-called superheat is a part of waste heat that can be recovered for useful purposes (usually to heat process water) through the use of a Heat Recovery Unit.

A Heat Recovery Unit is a special purpose heat exchanger specifically designed to:

- 1) Remove the heat represented by 2-2a in Figure 2 in an effective manner.
- 2) Improve overall system efficiency by partially unloading condenser.
- 3) Protect against contamination of potable water via double wall construction.
- 4) Offer mechanical clean ability to quickly restore full capacity should fouling occur.
- 5) Minimal pressure drop across the heat exchanger to minimize the pumping losses.

Figure 3 shows a typical installation of an HRU in an air conditioning system. The HRU intercepts the hot discharge gas before it goes to the system condenser. When properly sized and installed, only the device harvests only the superheat represented by 2-2a in Figure 2. In the process, it removes this amount of load from the system condenser, thereby allowing it to devote its full surface to condensing without the burden of desuperheating.

FIGURE 3



The HRU in Figure 3 is heating potable water for institutional uses such as food preparation, dishwashing, laundry, showers, etc. This heated potable water is deposited into an auxiliary tank, allowing the HRU to harvest heat without competing with the "primary" water tank. In effect, the HRU preheats the hot water for the "primary" hot water heater. The "primary" water heater only has to supply the difference (if any) between the desired water temperature and the auxiliary tank's temperature, thereby decreasing the amount of energy consumed by the "primary" water and saving money.

The amount of waste heat recoverable in any installation is dependent upon many factors. Among them are: (1) The discharge temperature of the compressor {largely determined by the ambient conditions or "sink temperature" i.e. the temperature of the outside air (if air cooled) or the temperature of the process water (if water cooled)}, (2) The number of hours per day and days per year that the air conditioning operates and (3) The amount of hot water that can be utilized at the site. The first two factors are common sense; the last is not so obvious. Consider if no hot water was withdrawn from the auxiliary tank (i.e. no hot water usage), then the temperature of the auxiliary tank would continue to rise until it was nearly as hot as the discharge gas from the compressor. Under conditions of nearly equal temperatures the heat transferred from the hot discharge gas is negligible and no heat is recovered. If however, water

is withdrawn from the auxiliary tank, colder municipal water takes its place and the net temperature of the auxiliary tank decreases, resulting in more heat recovered from the HRU.

Typically the amount of superheat available for recovery is between 8% and 15% of the total work of compression. Due to the temperature of the auxiliary tank discussed above, a good rule of thumb is that only half of this amount can be recovered averaged over a full day.

The economic benefit of the HRU depends not only upon the amount of heat recovered, but upon the cost to recover this heat versus the cost of generating hot water using conventional means (natural gas, propane gas, fuel oil, electricity, etc.). The operating cost of the HRU is generally only the electricity to power the circulating pump; less than the average household light bulb (60 watts). Therefore the benefit of using heat recovery is generally cast in terms of ROI or 1 years to payback1 versus the initial installed cost. The HRU can also assist in reaching LEED goals.

Clearly, more equatorial regions, with warmer and more humid climates, will generally lead in terms of amount of heat recoverable (cooling degree-days being a strong indicator). Less equatorial regions can also yield surprisingly good ROI's depending upon the local costs of conventional power sources to heat hot water.

Summary:

This white paper is intended to introduce the concept of heat recovery from vapor compression air conditioning systems. Other variations on this theme are possible, such as transferring the heat to a process fluid like ethylene glycol and using the heat in industrial processes instead of potable water heating.

The Turbotec application engineering staff stands ready to assist customers with assessment of economic potential for heat recovery at specific sites and to provide implementation recommendations.

For additional information about Turbotec's Heat Recovery products, please go to:

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And go to either the [Enviro-Temp](#) (10 to 200 ton applications),
or go to the [Enviro-Pak](#) (1.5 to 5 ton applications) section.

Or contact Turbotec Products, Inc. at
651 Day Hill Rd.
Windsor CT, 06095
Ph: 1.860.731.4200
Fax: 1.860.683.2133