

## Thermodynamics and Refrigeration Cycles

Second law

$$\begin{aligned} \dot{Q}_2 &= \dot{m}(x_4 - x_2) - \frac{\dot{Q}_1}{T_0} \\ &= 345(0.0750 - 0.0761) - (-207/549.67) \\ &= 0 \text{ Btu/h} \cdot ^\circ\text{R} \end{aligned}$$

Expansion Device:  
Energy balance

$$\dot{Q}_3 = \dot{m}(h_7 - h_6) = 0$$

Second law

$$\dot{Q}_3 = \dot{m}(x_7 - x_6) = 345(0.0880 - 0.0750) = 1.725 \text{ Btu/h} \cdot ^\circ\text{R}$$

These results are summarized in Table 4. For the Carnot cycle,

$$\text{COP}_{\text{Carnot}} = \frac{T_0}{T_0 - T_2} = \frac{549.67}{70} = 6.852$$

The Carnot power requirement for the 2-ton load is

$$\dot{W}_{\text{Carnot}} = \frac{\dot{Q}_{\text{Carnot}}}{\text{COP}_{\text{Carnot}}} = \frac{24,000}{6.852} = 3502 \text{ Btu/h}$$

The actual power requirement for the compressor is

$$\begin{aligned} \dot{W}_{\text{comp}} &= \dot{W}_{\text{Carnot}} + \dot{I}_{\text{total}} T_0 \\ &= 3502 + 7.543 \times 549.67 = 7649 \text{ Btu/h} \end{aligned}$$

This result is within computational error of the measured power input to the compressor of 7633 Btu/h.

The analysis in Example 5 can be applied to any actual vapor compression refrigeration system. The only required information for second-law analysis is the refrigerant thermodynamic state points and mass flow rates and the temperatures in which the system is exchanging heat. In this example, the extra compressor power required to overcome the irreversibility in each component is determined. The component with the largest loss is the compressor. This loss is due to motor inefficiency, friction losses, and irreversibilities caused by pressure drops, mixing, and heat transfer between the compressor and the surroundings. Unrestrained expansion in the expansion device is the next largest (also a large loss), but could be reduced by using an expander rather than a throttling process. An expander may be economical on large machines.

All heat transfer irreversibilities on both the refrigerant side and the air side of the condenser and evaporator are included in the analysis. Refrigerant pressure drop is also included. Air-side pressure drop irreversibilities of the two heat exchangers are not included, but these are equal to the fan power requirements because all the fan power is dissipated as heat.

An overall second-law analysis, such as in Example 5, shows the designer components with the most losses, and helps determine which components should be replaced or redesigned to improve

**Table 4** Energy Transfers and Irreversibility Rates for Refrigeration System in Example 5

Component	$\dot{Q}$ , Btu/h	$\dot{W}$ , Btu/h	$\dot{I}$ , Btu/h $\cdot$ $^\circ$ R	$\dot{I}/\dot{I}_{\text{total}}$ , %
Evaporator	24,000	0	1,405	19
Suction line	586	0	0.279	4
Compressor	-494	7633	2,417	32
Discharge line	-1360	0	0.441	6
Condenser	-36,153	0	1,278	17
Liquid line	-207	0	0	0
Expansion device	0	0	1,725	23
<b>Totals</b>	<b>-7648</b>	<b>7633</b>	<b>7.543</b>	

performance. However, it does not identify the nature of the losses; this requires a more detailed second-law analysis of the actual processes in terms of fluid flow and heat transfer (Liang and Kuehn 1991). A detailed analysis shows that most irreversibilities associated with heat exchangers are due to heat transfer, whereas air-side pressure drop causes a very small loss and refrigerant pressure drop causes a negligible loss. This finding indicates that promoting refrigerant heat transfer at the expense of increasing the pressure drop often improves performance. Using a thermoeconomic technique is required to determine the cost/benefits associated with reducing component irreversibilities.

### 3. ABSORPTION REFRIGERATION CYCLES

An absorption cycle is a heat-activated thermal cycle. It exchanges only thermal energy with its surroundings; no appreciable mechanical energy is exchanged. Furthermore, no appreciable conversion of heat to work or work to heat occurs in the cycle.

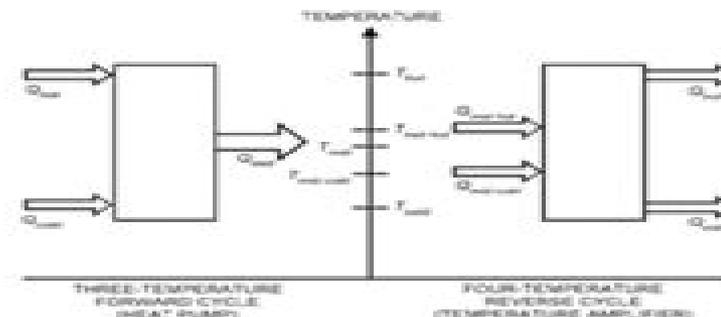
Absorption cycles are used in applications where one or more of the exchanges of heat with the surroundings is the useful product (e.g., refrigeration, air conditioning, and heat pumping). The two great advantages of this type of cycle in comparison to other cycles with similar product are

- No large, rotating mechanical equipment is required
- Any source of heat can be used, including low-temperature sources (e.g., waste heat, solar heat)

#### 3.1 IDEAL THERMAL CYCLE

All absorption cycles include at least three thermal energy exchanges with their surroundings (i.e., energy exchange at three different temperatures). The highest- and lowest-temperature heat flows are in one direction, and the mid-temperature one (or two) is in the opposite direction. In the forward cycle, the extreme (hottest and coldest) heat flows are into the cycle. This cycle is also called the heat amplifier, heat pump, conventional cycle, or Type I cycle. When extreme-temperature heat flows are out of the cycle, it is called a reverse cycle, heat transformer, temperature amplifier, temperature booster, or Type II cycle. Figure 16 illustrates both types of thermal cycles.

This fundamental constraint of heat flow into or out of the cycle at three or more different temperatures establishes the first limitation on cycle performance. By the first law of thermodynamics (at steady state),



**Fig. 16** Thermal Cycles

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**Victor M. Corman**



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*Noise Control* Colin H. Hansen, Kristy L. Hansen, 2021-08-05 The second edition of Noise Control From Concept to Application newly expanded and thoroughly updated now includes 180 graded problems with solutions plus 100 end of chapter problems with solutions available for instructors on the authors website Working from basic scientific principles the authors show how an understanding of sound can be applied to real world settings working through numerous examples in detail and covering good practice in noise control for both new and existing facilities It covers the essential topics for industrial noise control acoustics noise criteria hearing damage risk noise assessment measures measurement instrumentation sound source types including the calculation and measurement of their output power sound propagation outdoors sound in rooms sound absorbing materials sound transmission through partitions and enclosures noise barriers reactive and dissipative muffler noise reduction and muffler design considerations such as pressure loss and self noise generation Detailed explanations of important concepts make this textbook easy to understand by engineering and science undergraduates as well as professionals with no background in acoustics Authors website [www.causalsystems.com](http://www.causalsystems.com) Colin H Hansen is Emeritus Professor in Mechanical Engineering at the University of Adelaide Australia and past President of the International Institute of Acoustics and Vibration Kristy L Hansen is a Senior Lecturer in Mechanical Engineering at Flinders University Australia and holder of the Australian Research Council s Discovery Early Career Researcher Award [ASHRAE Handbook](#) ,1989 [Development of Diagnostic and Measurement and Verification Tools for Commercial Buildings](#) Philip Haves, Lawrence Berkeley National Laboratory, 2014 [Proceedings CLIMA 2022](#) Laure Itard, Lada Hensen-Centnerová, Atze Boerstra, Philomena Bluysen, Jan Hensen, Tillmann Klein, Marcel Loomans, Pieter Pauwels, Christian Struck, Martin Tenpierik, Bob Geldermans, 2022-10-12 The 14th REHVA HVAC World Congress CLIMA2022 challenges advances in

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**ASHRAE Handbook of Fundamentals** American Society of Heating, Refrigerating and Air-Conditioning Engineers,1972

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*ASHRAE Handbook & Product Directory* American Society of Heating, Refrigerating and Air-Conditioning Engineers,1980

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