

20TH ANNIVERSARY!

Eighth Edition

**PRESSURE
ENTHALPY**

WITHOUT TEARS

Eugene Silberstein, M.S., CMHE, BEAP



esco institute

A guide to plotting air conditioning and refrigeration systems on pressure-enthalpy diagrams...and then some!

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The first edition of this book was dedicated to my dear friend Dan Holohan, for the gentle but firm nudging to get this project completed, and the Heating, Ventilation, Air Conditioning and Refrigeration students at Suffolk County Community College, Class of 2006.

Twenty years later, this work has become a proven entity for the thousands of individuals who have learned and benefited from its content. So, it is to these dedicated HVACR students and professionals to whom this edition is dedicated.

ABOUT THE AUTHOR

Eugene Silberstein



Over the past forty-five years, Eugene has been involved in all aspects of the HVACR industry from field technician and system designer to company owner, teacher, administrator, consultant, college professor, and author. Eugene is presently serving as the National Programs Director at HVAC Excellence, a division of ESCO Institute, based in Mount Prospect, IL. Eugene has over thirty years of teaching experience and has taught at several private, secondary and postsecondary institutions. He can be seen at many national HVACR events, conventions and conferences where he, as a popular guest presenter, speaks on many different topics important to our industry.

Eugene earned his dual bachelor's degree from The City College of New York, where he studied electrical engineering, economics, operations management marketing, and finance. He earned his Master of Science degree from Stony Brook University, where he specialized in Energy and Environmental Systems, studying renewable and sustainable energy sources including wind, solar, geothermal, biomass and hydropower. He earned his Certified Master HVACR Educator (CMHE) credential in 2010 from HVAC Excellence. Eugene also carries the BEAP credential issued by ASHRAE, which classifies him as a Building Energy Assessment Professional.

As an active member of various industry organizations, including ASHRAE and IEEE, Eugene served as the subject matter expert and wrote the production scripts for dozens of educational videos directly relating to our industry in addition to co-authoring the number one HVACR textbook in the industry, "*Refrigeration and Air Conditioning Technology*", presently in its 10th Edition" published by Cengage Learning. This book is used in over 1,200 schools both in this country and abroad to help individuals learn, and master, the skills required to service, install, design, service and troubleshoot HVACR equipment.

Other book credits include *Refrigeration and Air Conditioning Technology*, 6th, 7th, 8th, 9th, and 10th Edition (Cengage), *The Complete HVACR Lab Manual*, 1st and 2nd Editions (Cengage), *Residential Construction Academy: HVAC*, 1st and 2nd Edition (Cengage), *Heat Pumps*, 1st and 2nd Editions (Cengage), *Print Reading for HVAC*, 1st and 2nd Editions (Goodheart-Willcox, 2021, 2025), *Psychrometrics Without Tears* (ESCO Institute, 2014), and *Electricity Theory and Applications* (Goodheart-Willcox, 2026). Eugene has also written numerous articles for industry newspapers and magazines.

Eugene was selected as one of the top three HVACR instructors in the country for the 2005/2006, 2006/2007 and 2007/2008 academic school years by the Air Conditioning and Refrigeration Institute (ARI), now AHRI, and the Air Conditioning, Heating and Refrigeration (ACHR) News. In January 2024, Eugene received HVAC Tactical's lifetime achievement award, which was presented at their 2024 awards ceremony in Chicago, IL.

ABOUT THE BOOK

Over the years, much has been written on the subject of pressure-enthalpy. A good portion of this material has been geared toward engineers for the sole purpose of designing HVACR systems. Although many engineers, system designers, project supervisors, and higher level managers have found the content in this book to be extremely useful, the target audience for this work includes HVACR students, instructors, and field service technicians.

This book presents the concepts of pressure enthalpy in a manner that has wide-ranging appeal that encourages the use of this valuable tool as an aid in the maintaining, installing, evaluating, and starting up of HVACR systems and equipment.

The field service technician's most useful and reliable tools have traditionally been a thermometer, a refrigerant gauge manifold and a keen eye. The thermometer provides vital information about the sensible heat transfers that take place in an air conditioning or refrigeration system. The gauge manifold, however, provides information about the latent heat transfers that are taking place in the system. Both of these tools provide integral pieces to the puzzle we call an air conditioning or refrigeration system. Separately, they have limited value. However, when used together, they form the basis for sound, systematic troubleshooting and system evaluating techniques and processes.

In the field, service personnel often face practical challenges. For example, to visually inspect a system's outdoor, or condensing unit, a trip to the backyard is often required. To check a system's indoor unit or evaporator, climbing into the attic or crawlspace, or heading down into the basement is required. Because of the very nature of the systems on which we work, it is impossible to get a complete picture of the system, and how it operates, at a single glance. Enter the pressure enthalpy chart, which enables us to do just that. Armed with a properly-completed pressure enthalpy chart, field service technicians can evaluate a system's sensible and latent heat transfers, while observing the performance of the compressor, condenser, metering device and evaporator... all at the same time.

Pressure Enthalpy Without Tears starts out by reviewing the four main system components that form the basic vapor-compression refrigeration cycle, as well as the concepts of superheat, subcooling and the temperature/pressure relationship. This content review provides a valuable and insightful resource for the seasoned professional, while providing those new to the industry vital information and tools they'll need to hit the ground running.

With the fundamentals covered, the book then turns to pressure enthalpy, where the discussion begins with the basics of the chart itself, giving an overview of the meaning and purpose for every line on the chart. Simplified charts are used to enable the reader to gain a solid foundation of the concepts that will be built upon as the book progresses.

The plotting of actual systems follows next. This first involves plotting the operational characteristics of systems that are operating correctly. This allows the reader to see what properly operating systems look like on the chart. With a fair amount of practice, the process of plotting a system on a pressure-enthalpy chart can take as little as two minutes.

With the completed plot in hand, we next turn to the calculation and evaluation of the system parameters that include net refrigeration effect, heat of work, heat of compression, mass flow rate per ton, theoretical horsepower per ton, total heat of rejection, mass flow rate of the system,

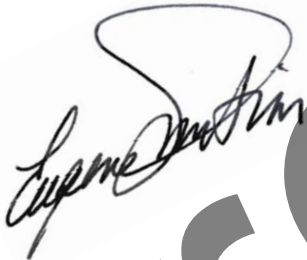
evaporator capacity, condenser capacity, compressor capacity, coefficient of performance, energy efficiency ratio (EER and EER2), and seasonal energy efficiency ratio (SEER and SEER2). It is important to note that only basic mathematical operations (addition, subtraction, multiplication, and division) are required to make these all-important calculations.

Once we have learned to plot systems on the pressure enthalpy chart and perform basic calculations, we then start looking at systems that are operating with malfunctions such as dirty air filters, refrigerant overcharge, refrigerant undercharge, etc. By interpreting the parameters calculated earlier, readers will learn to analyze and troubleshoot malfunctioning systems with speed, accuracy, and precision. Detailed charts are provided that compare the malfunctioning system to the same system if it were operating correctly. The properly operating system, as well as the malfunctioning system are plotted on the same pressure-enthalpy chart, in an overlaying fashion, so the reader can easily see the differences between the two. It is here that the reader can appreciate the power of the pressure enthalpy chart and its usefulness to effectively and accurately start up, troubleshoot and evaluate air conditioning and refrigeration systems.

In the appendices, you will find a wide range of important information including blank pressure-enthalpy charts for 18 different refrigerants, troubleshooting reference charts, a test-your pressure-enthalpy knowledge quiz, and a whole lot more.

I truly hope that the material contained in this book proves as useful to you as it has to me over the years. Feel free to email me directly at eugene.silberstein@yahoo.com or eugene@escogroup.org. I'd love to hear from you!

Enjoy.



Eugene Silberstein

WHAT'S NEW AND EXCITING IN THIS EDITION

I am extremely excited about this edition of *Pressure Enthalpy Without Tears*. In addition to celebrating its 20th anniversary, here are some neat things that have been added to this version of the book:

- Revised temperature/pressure charts to include R-32, R-454B, R-1234yf, in addition to some of our old favorites
- Updated/revised examples to reflect Low-GWP refrigerants
- Revised blank pressure-enthalpy chart for R-22
- Revised blank pressure-enthalpy chart for R-32
- Revised blank pressure-enthalpy chart for R-134a
- Revised blank pressure-enthalpy chart for R-401A
- Revised blank pressure-enthalpy chart for R-402A
- Revised blank pressure-enthalpy chart for R-402B
- Revised blank pressure-enthalpy chart for R-404A
- Revised blank pressure-enthalpy chart for R-407C
- Revised blank pressure-enthalpy chart for R-410A
- Revised blank pressure-enthalpy chart for R-422B
- Revised blank pressure-enthalpy chart for R-438A
- Revised blank pressure-enthalpy chart for R-449A
- Revised blank pressure-enthalpy chart for R-452B
- Revised blank pressure-enthalpy chart for R-454B
- Revised blank pressure-enthalpy chart for R-463A
- Revised blank pressure-enthalpy chart for R-513A
- Revised blank pressure-enthalpy chart for R-514A
- Revised blank pressure-enthalpy chart for R-1234yf
- More examples on how to plot systems on the pressure-enthalpy chart
- New information on efficiency ratings including EER2, SEER2 and HSPF2
- New information on system troubleshooting
- Pressure-enthalpy troubleshooting overlay charts

PRESSURE ENTHALPY WITHOUT TEARS – 8th Edition

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Preview

SECTION I: THE BASIC REFRIGERATION CYCLE

Repeating Versus Non-Repeating Cycles

Before we begin our discussion of pressure-enthalpy, system plotting and evaluation, and system capacity and efficiency, a brief, graphical review of the basic refrigeration cycle is in order. This review presents the basic refrigeration cycle in a manner that will ease us into our discussion of pressure-enthalpy. As such, this is an important portion of the book, so please do not skip over it. Once we've created a visual representation of the basic vapor-compression refrigeration cycle, you'll quickly see how easily this image transitions seamlessly into a completed pressure-enthalpy plot. The completed pressure-enthalpy plot will enable us to evaluate the system as a whole, determine system capacity and efficiency, while still being able to concentrate on specific system parameters and conditions as needed.

The first thing that needs to be addressed is the fact that the basic vapor-compression refrigeration cycle is a repeating cycle, Figure 1. A repeating cycle starts and ends at the same point. Simply stated, when refrigerant has completed one complete path through the system, it returns to the same place it started from and is in the same exact condition as when it started. It should also be noted that, as the refrigerant circulates through the system, the refrigerant supply is not depleted. We can easily compare our repeating cycle to a non-repeating cycle, Figure 2, which starts and ends at different points, by examining the fundamental operation of a car engine.

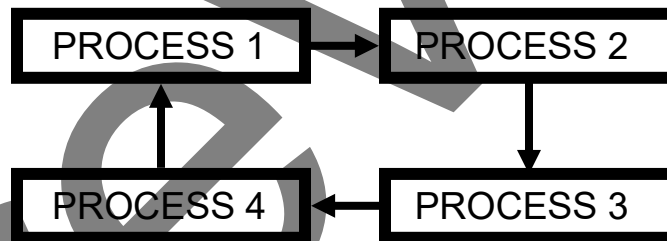


Figure 1. Graphical representation of a repeating cycle.

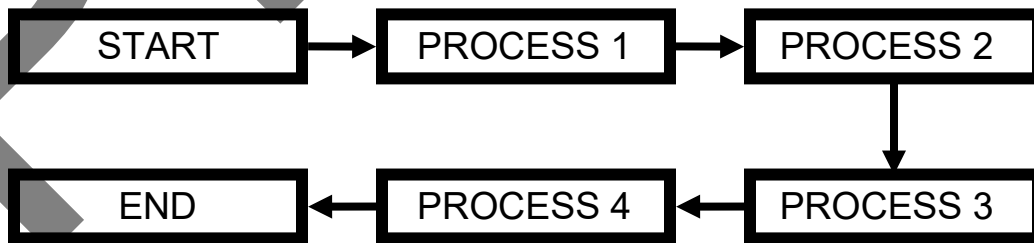


Figure 2. Graphical representation of a non-repeating cycle.

pressure of 67 psig. Pressures very close to this value are identified in both the bubble column (67.5 psig) and the dew column (67.1 psig). The next step is to move to the left from each pressure value and record the saturation temperature that corresponds to this pressure, Figure 21. These two temperature values, 18°F and 16°F, represent the limits of the refrigerant’s temperature glide. Taking the difference between these two values (18°F - 16°F) gives us the temperature glide. It can be seen that the temperature glide for R-454B is about 2°F. The bubble and dew values will be revisited later on as these values are also used to evaluate the performance of air-conditioning and refrigeration systems.

Temp (°F)	Pressure (psig)				
	R-22	R-32	R-410A	R-454B	
				Bubble	Dew
-25	7.5	22.3	21.8	20.1	18.5
-20	10.2	26.8	26.2	24.3	22.6
-15	13.2	31.7	31	28.9	27
-10	16.5	37.1	36.3	33.9	31.8
-5	20.1	42.9	42	39.4	37
0	24	49.3	48.2	45.3	42.7
2	25.7	51.9	50.8	47.8	45.1
4	27.4	54.7	53.5	50.3	47.6
6	29.2	57.5	56.3	53	50.1
8	31	60.5	59.2	55.7	52.7
10	32.8	63.5	62.2	58.5	55.5
12	34.8	66.6	65.2	61.5	58.2
14	36.8	69.8	68.4	64.4	61.1
16	38.8	73.1	71.6	67.5	64.1
18	40.9	76.5	74.9	70.7	67.1
20	43.1	80	78.2	75	70.9

Figure 21. The temperature glide of a refrigerant can be estimated using the temperature/pressure chart.

Example #1: Consider an R-410A air conditioning system that has a low-side pressure of 118.6 psig. At what temperature is the refrigerant undergoing a liquid-to-vapor change of state. In other words, what is the boiling temperature of the refrigerant?

Example #1 Solution: We are looking for the boiling temperature of the refrigerant, which means we want the saturation temperature for that refrigerant at a pressure of 118.6 psig. In the main body of our temperature/pressure chart (the pressures) we locate 118.6 in the R-410A column. Once this is located, we move over to the left and read the saturation temperature of that refrigerant at the given pressure. In this case, the saturation temperature is 40°F, Figure 22. At 118.6 psig, R-410A boils at 40°F.

condenser saturation temperature, which is 120°F. Once the desuperheated vapor has cooled down to the saturation temperature, any additional heat transfer from the refrigerant to the surrounding air will initiate the condensing (vapor-to-liquid) process, Figure 29.

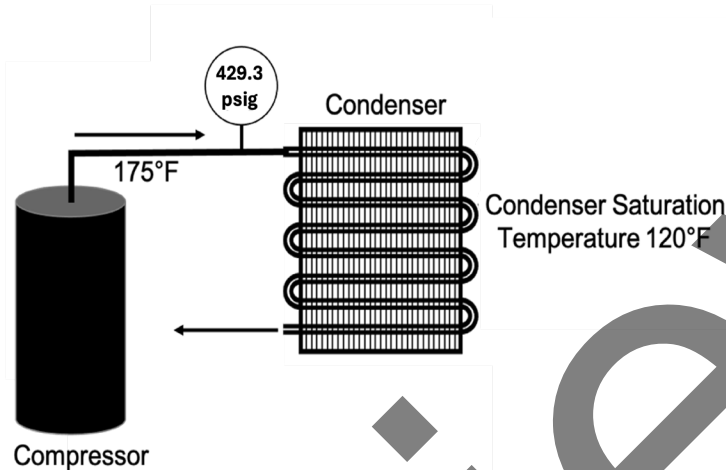


Figure 29. Hot gas from this R-32 compressor must give up 55 degrees of sensible heat (superheat) before the vapor can begin to condense.

Once the refrigerant has desuperheated to the condenser saturation temperature and the condensing process has begun, the temperature of the refrigerant will remain constant, but the vapor/liquid percentages will change. Immediately after the desuperheating process has completed, the refrigerant will be 100% vapor and 0% liquid. As the change of state continues, the percentage of liquid in the mixture will increase and the percentage of vapor will decrease.

The condensing process, the second process that takes place in the condenser, takes place as the 120-degree saturated vapor refrigerant transfers heat to the 95-degree air that is passing over the condenser coil. This latent heat transfer will continue until the refrigerant is 100% liquid at a temperature of 120°F.

Once the refrigerant has completely condensed, the 120°F liquid refrigerant will continue to give up heat to the 95-degree air that is passing over the coil. This sensible heat transfer will cause the temperature of the liquid refrigerant to cool down below the condenser saturation temperature. This process is called subcooling.

Condenser subcooling is defined as the amount of sensible heat that is given up by the refrigerant in the condenser coil after all of the vapor has condensed.

The amount of condenser subcooling is determined, in part, by the point at which the last bit of vapor is present in the condenser coil. If there is vapor close to the outlet of the condenser coil, the amount of condenser subcooling will be low. However, if the last bit of vapor is closer to the inlet of the condenser coil, the amount of condenser subcooling

THE PRESSURE-ENTHALPY CHART

The Basic Refrigeration Cycle and the Pressure-Enthalpy Chart: Side-by-Side

Having discussed the basic refrigeration cycle and the basic construction of the pressure-enthalpy chart, we will now compare these two representations, side-by-side. The first thing to note is that during our discussion of both the refrigeration cycle and the pressure-enthalpy chart, the same units and scales were used on each axis. The X-axis represents heat content, expressed in Btu/lb, and the Y-axis represents pressure, Figure 61.

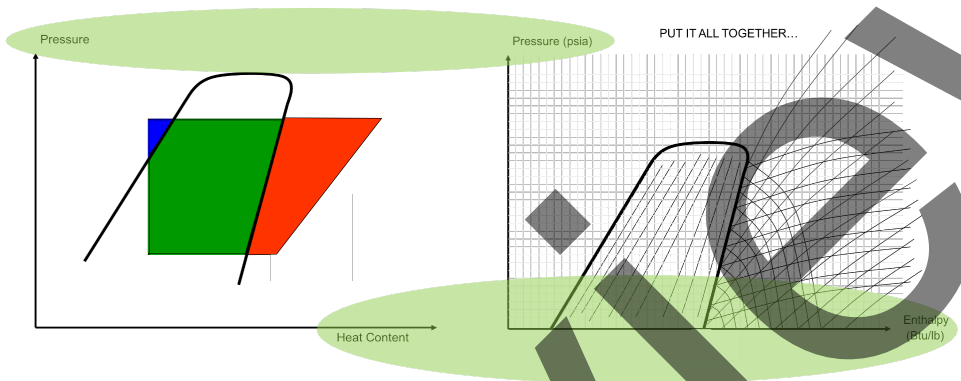


Figure 61. The Y-axis represents pressure and the X-axis represents heat content.

Both the pressure-enthalpy chart and the refrigeration cycle have regions where saturated refrigerant is found, Figure 62. These are the green region on the left side of the figure and the area under the saturation curve on the right side of the figure. It is within these regions that refrigerant is a mixture of liquid and vapor. Any change in heat content will result in changes to refrigerant quality. Recall that heat transfers that take place under the saturation curve are latent heat transfers.

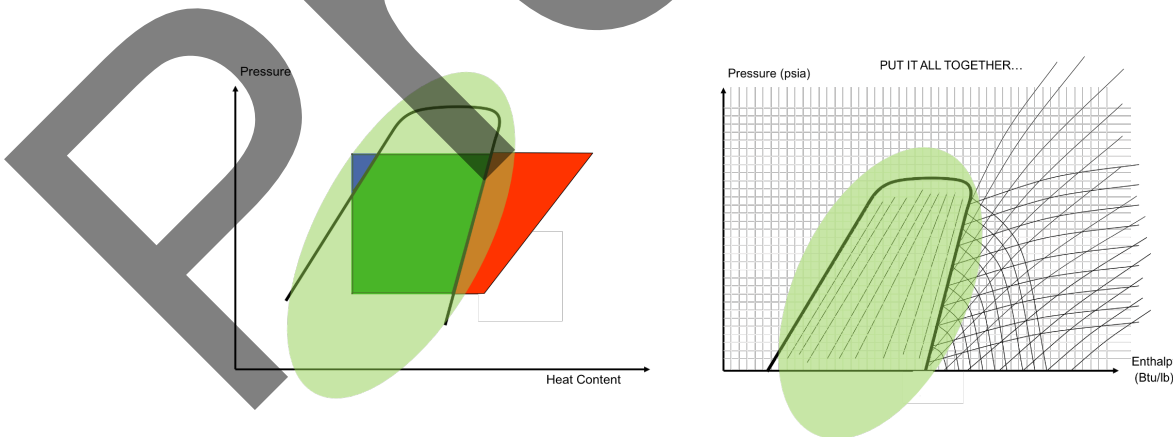


Figure 62. Saturated regions on the pressure-enthalpy chart and the basic refrigeration cycle.

Step 9: Draw vertical lines to obtain enthalpy readings.

Drawing vertical lines through points A, B, C, D and E will give the heat content (enthalpy) readings for the system. Depending on the chart, enthalpy readings can be obtained at either the top or bottom of the chart. Make note of these values as they will be used to perform the system calculations, Figure 98. The values obtained for our example should be very close to the following:

- Heat content at point “A”: 116 Btu/lb
- Heat content at point “B”: 116 Btu/lb
- Heat content at point “C”: 224 Btu/lb
- Heat content at point “D”: 227 Btu/lb
- Heat content at point “E”: 248 Btu/lb

Notice that the heat content at point “A” is the same as the heat content at point “B”. This is because of the adiabatic process within the metering device where the heat content remains the same, while the temperature and pressure of the refrigerant change.

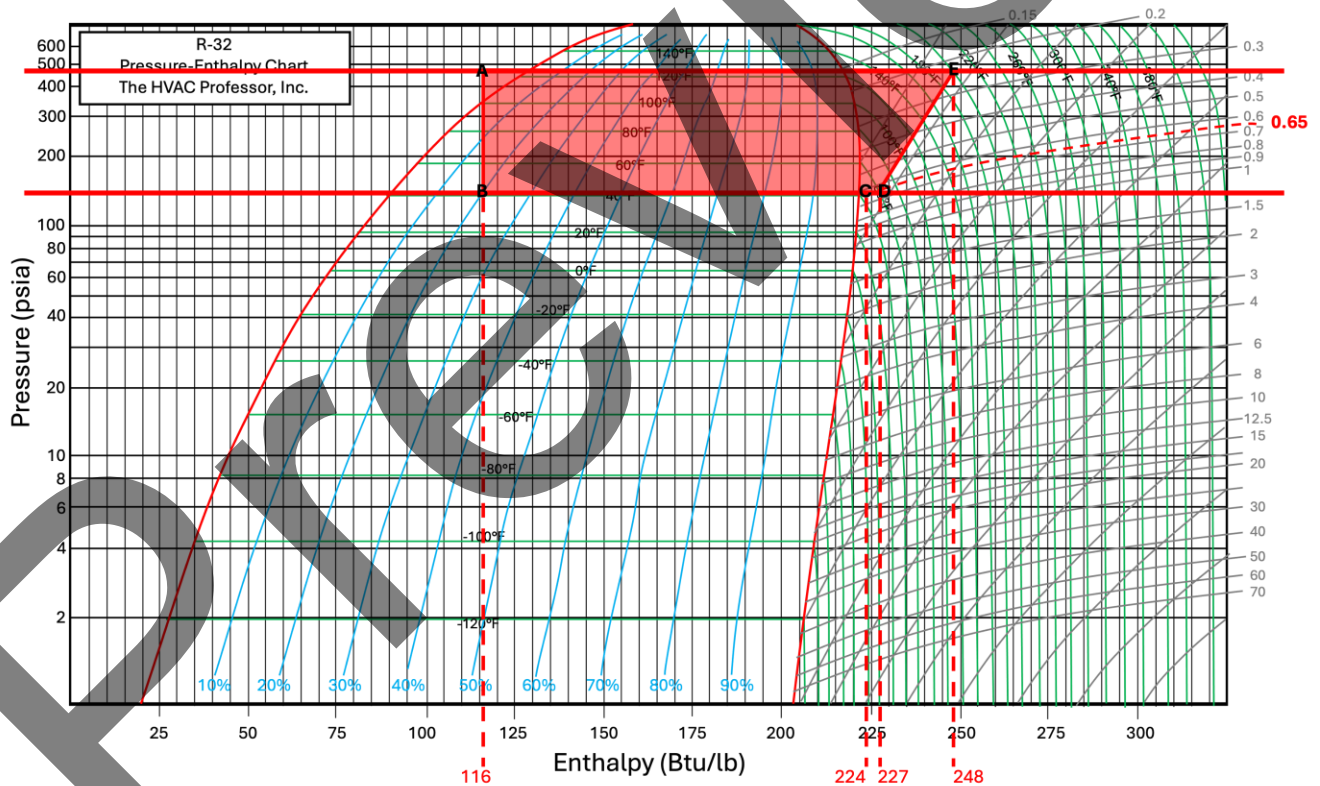


Figure 98. Completed pressure-enthalpy plot with enthalpy values for key system points identified.

Section III: Plotting the System and Performing the Calculations

evaporator is operating with 0 degrees of evaporator superheat. As you look over the completed plot for this system, note that the evaporator outlet, at Point C, lies directly on the right edge of the saturation curve.

The completed pressure-enthalpy plot for this system is provided in Figure 116.

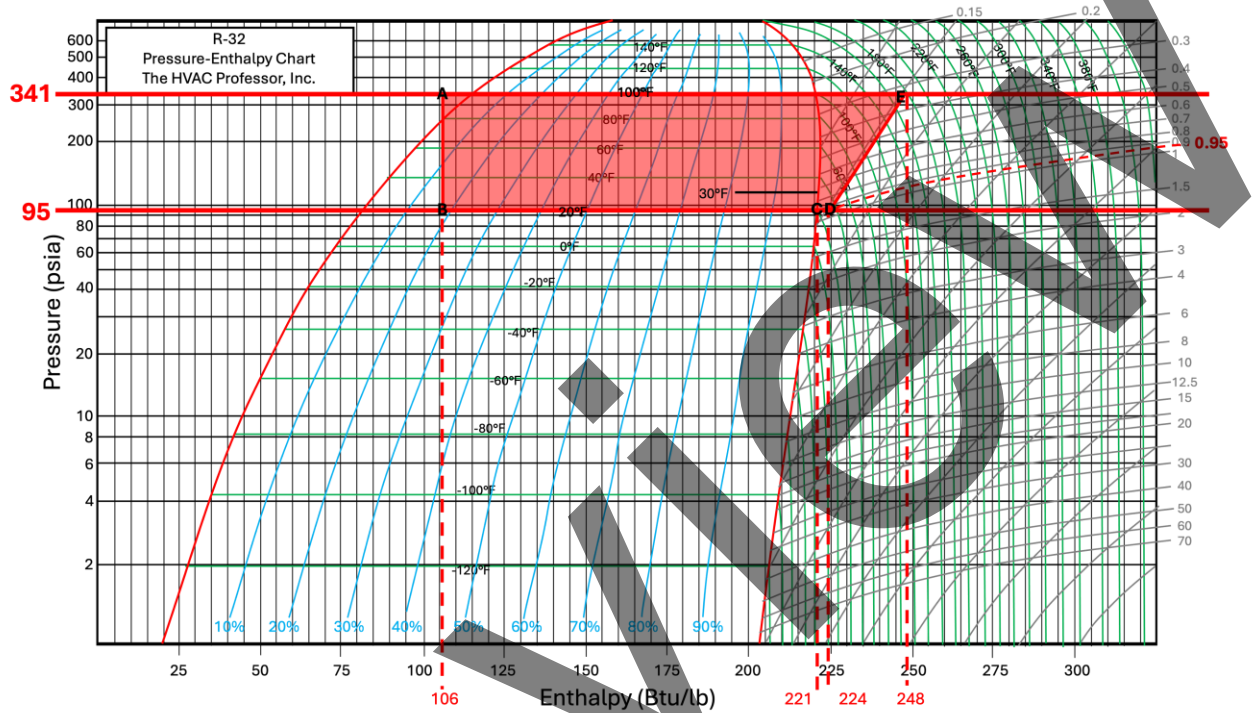


Figure 116. Completed pressure-enthalpy plot for System #4 with enthalpy values for key system points identified.

The pressure, enthalpy and specific volume values for this system are as follows:

- High-side pressure: 326 psig (341 psia)
- Low-side pressure: 80 psig (95 psia)
- Heat content at point “A”: 106 Btu/lb
- Heat content at point “B”: 106 Btu/lb
- Heat content at point “C”: 221 Btu/lb
- Heat content at point “D”: 224 Btu/lb
- Heat content at point “E”: 248 Btu/lb
- Specific volume at the inlet of the compressor: 0.95 ft³/lb

Here are the calculations for this system:

Section IV: System Comparison

To begin our comparison of these two properly operating systems, it is important to mention that, for the sake of simplicity and to convey the concepts as clearly as possible, singular changes have been made to the system's performance. By changing only 1 or 2 system operating characteristics, the effects of the change can be more readily observed. In reality, when an operating characteristic changes, such as airflow through an evaporator coil, multiple operational changes in the system occur.

We will start our comparison by discussing the changes in compression ratio and its effect on system performance. In both sample system #1 and system #2, the high-side pressure remained the same at 460 psig (475 psia). System #1 is operating properly with a 40°F evaporator coil and a low-side pressure of 121 psig (136 psia), while System #2, also properly operating, has a 50°F evaporator coil and a low-side pressure of 146 psig (161 psia).

By increasing the evaporator saturation pressure from 121 psig (System #1) to 146 psig (System #2), the distance between the high side pressure and the low side pressure decreases, causing the compression ratio to decrease. In this case, it can be seen that the compression ratio decreased from 3.49:1 for System #1 to 2.95:1 for System #2.

A decrease in compression ratio leads to a decrease in the heat of work (HOW), a decrease in the heat of compression (HOC), and an increase in both the net refrigeration effect (NRE) and the system's mass flow rate (MFR/system), Figure 120.

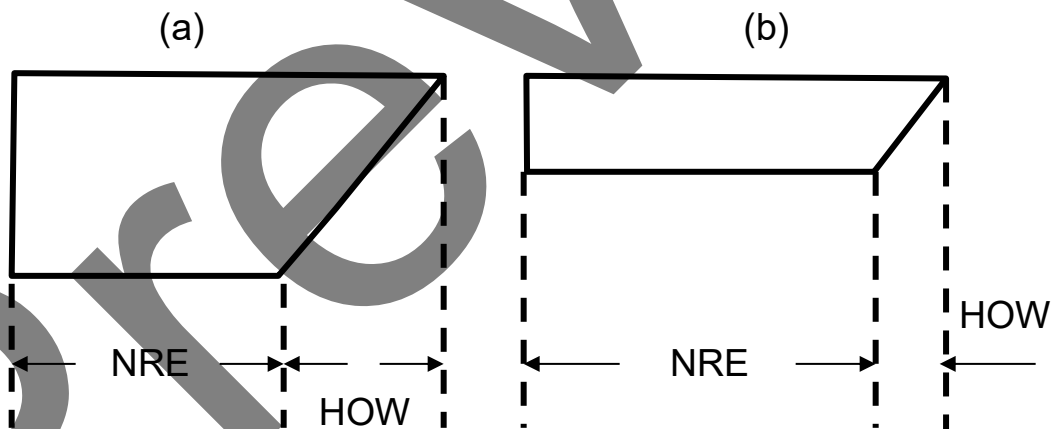


Figure 120. (a) A system with a high compression ratio will have a larger heat of work, which results in a lower mass flow rate for the system and a lower net refrigeration effect. (b) A lower compression ratio reduces the heat of work and facilitates a higher mass flow rate for the system and a higher net refrigeration effect.

Any increase in head pressure or decrease in suction pressure will cause the compression ratio to increase, while any decrease in head pressure or increase in suction pressure will cause the compression ratio to decrease. Higher compression ratios lead to system inefficiencies.

SYSTEM COMPARISON: SYSTEM #1 VS. SYSTEM #4

Our discussion continues by looking at our properly operating air-conditioning system with its 40°F evaporator coil and comparing it to a system that is operating with reduced airflow through the indoor evaporator coil. These two systems were plotted on pressure enthalpy charts in the previous section. Feel free to refer to Page 99 for System #1 and Page 129 for System #4.

A system that is operating with reduced airflow through the evaporator coil will typically operate with the following conditions:

- Lower than normal high-side pressure
- Lower than normal low-side pressure
- Normal condenser subcooling
- Lower than normal evaporator superheat

These changes in system performance were accounted for in the pressure enthalpy plot for System #4. The results of the calculations that were performed for these two systems are tabulated in Figure 122. In this figure, the right-hand column indicates whether a particular system parameter has either increased, decreased, or remained the same.

	SYSTEM #1	SYSTEM #4	
	Normal Operation @ 40°F	Reduced Indoor Airflow	Increase/Decrease
Compression Ratio	3.49:1	3.59:1	Increase
NRE	108 Btu/lb	115 Btu/lb	Increase
HOC	24 Btu/lb	27 Btu/lb	Increase
HOW	21 Btu/lb	24 Btu/lb	Increase
THOR	132 Btu/lb	142 Btu/lb	Increase
COP	4.5	4.3	Decrease
MFR/ton	1.85 lb/min/ton	1.74 lb/min/ton	Decrease
THp/Ton	0.92 Hp/ton	0.98 Hp/ton	Increase
MFR/system	10.1 lb/min	8.84 lb/min	Decrease
Evaporator Capacity	65,448 Btu/hour	60,996 Btu/hour	Decrease
Evaporator Tonnage	5.45 tons	5.08 tons	Decrease
Condenser Capacity	79,992 Btu/hour	75,317 Btu/hour	Decrease
Condenser Tonnage	6.67 tons	6.28 tons	Decrease
Capacity/compressor	6.57 ft ³ /min	8.4 ft ³ /min	Increase
EER	15.35	14.67	Decrease
EER2	14.59	13.94	Decrease
SEER	18.42	17.6	Decrease
SEER2	17.5	16.73	Decrease

Figure 122. Side-by-side comparison of System #1 and System #4.

Underfeeding Metering/Expansion Device

A system operating with an underfeeding metering/expansion device is typically characterized by:

- Higher than desired high-side pressure
- Lower than desired low-side pressure
- Higher than desired condenser subcooling
- Higher than desired evaporator superheat

Consider the superimposed plots shown in Figure 131. The green plot represents our baseline plot, while the red plot is our actual system. Notice how, for a system that is operating with an underfeeding metering/expansion device, the plot expands out in all directions. So, if you see this, chances are that the system is operating with an underfeeding metering/expansion device!

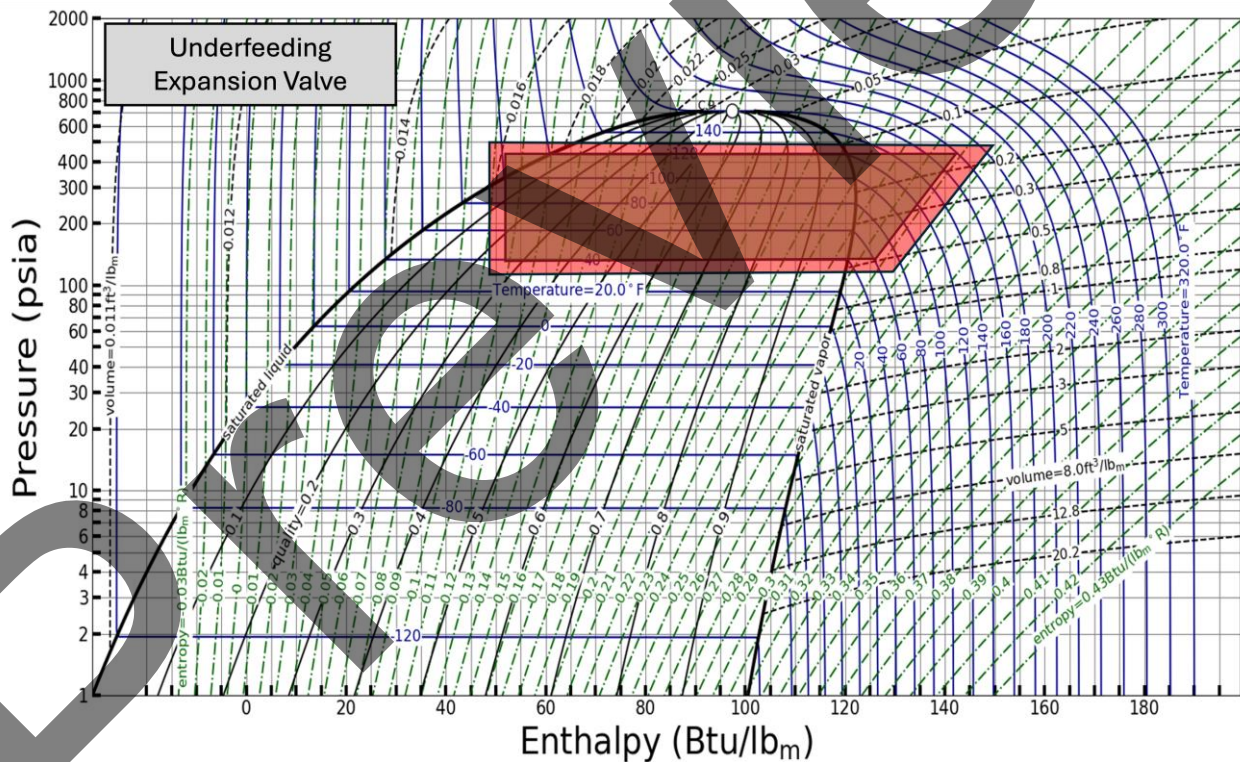


Figure 131. Pressure-enthalpy chart indicating a system with an underfeeding metering/expansion device.

Heat Pump Stuff

Possible Causes for High Head Pressure and Low Suction Pressure (System Operating in the Heating Mode. Cooling Mode Operating Correctly)

- ✓ Indoor check valve stuck in the closed position
- ✓ Outdoor metering device stuck in the closed position
- ✓ Outdoor filter drier clogged

Possible Causes for Low Head Pressure and High Suction Pressure (System Operating in the Heating Mode. Cooling Mode Operating Correctly)

- ✓ Outdoor check valve stuck in the open position
- ✓ Indoor metering device stuck in the open position

Possible Causes for Low Head Pressure and High Suction Pressure (System Operating in the Cooling Mode. Heating Mode Operating Correctly)

- ✓ Indoor check valve stuck in the open position
- ✓ Indoor metering device stuck in the open position

Possible Causes for High Head Pressure and Low Suction Pressure (System Operating in the Cooling Mode. Heating Mode Operating Correctly)

- ✓ Outdoor check valve stuck in the closed position
- ✓ Indoor metering device stuck in the closed position
- ✓ Indoor filter drier clogged

Possible Causes for Low Head Pressure and High Suction Pressure While Operating in Either Mode (Both modes malfunctioning)

- ✓ Internal reversing valve leak
- ✓ Damaged compressor valves

SECTION VI
TEST YOUR PRESSURE ENTHALPY KNOWLEDGE

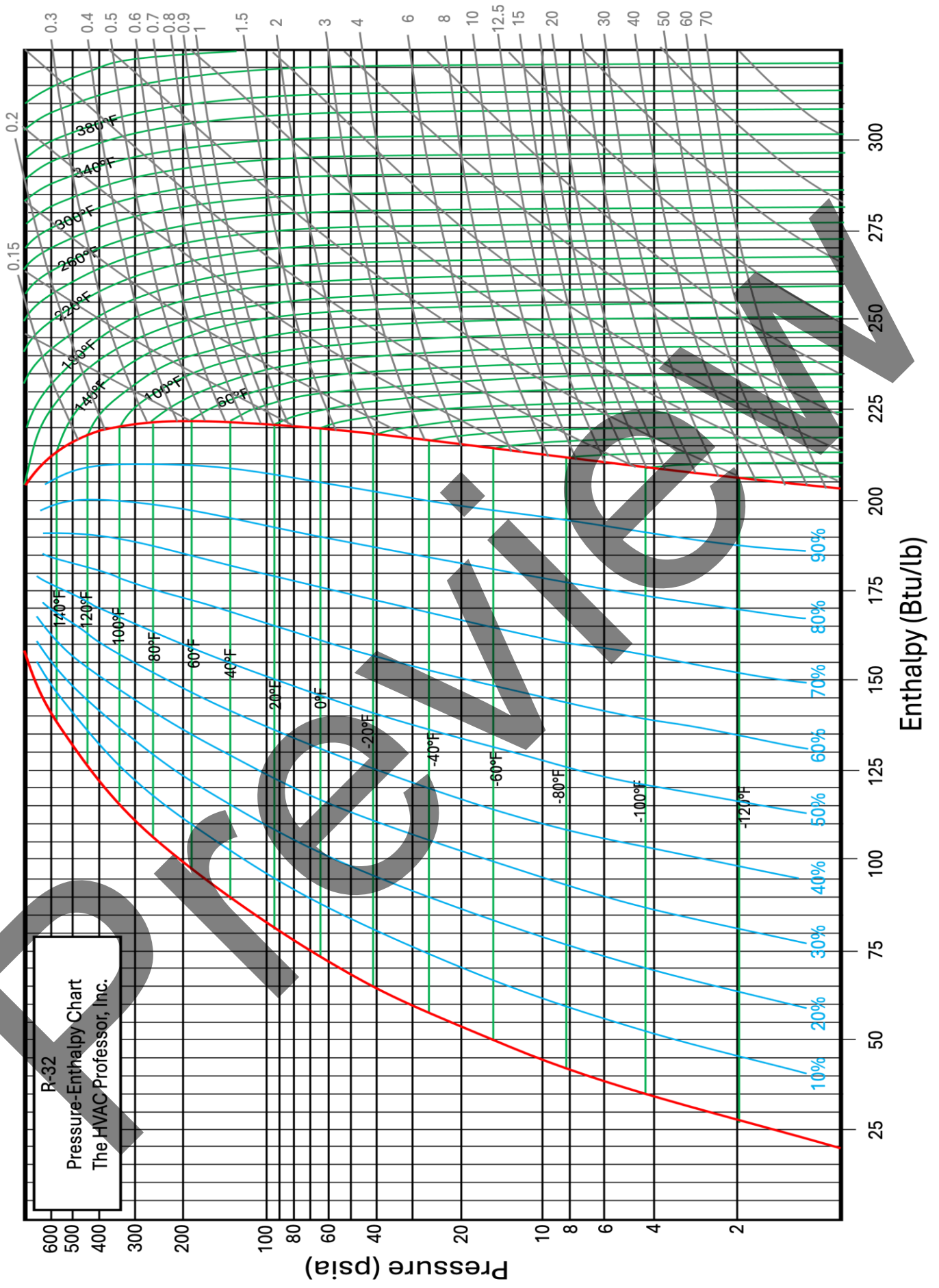
01. Explain why the MFR/ton increases as the NRE decreases.
02. Explain why the THp/ton increases as the compression ratio increases.
03. What happens to the EER2 as the compression ratio increases? Why?
04. Reducing the amount of heat absorbed into the system through the suction line will affect the HOC. Will the HOC increase or decrease? Why?
05. Reducing the amount of heat absorbed into the system through the suction line will affect the COP. Will the COP increase or decrease? Why?
06. An air conditioning system is equipped with an automatic expansion valve. The condenser coil is blocked with dirt. What will happen to the system's compression ratio? What will happen to the system's HOW? What will happen to the system's mass flow rate? What will happen to the evaporator's capacity?

SECTION VII
BLANK PRESSURE-ENTHALPY CHARTS

The pages that follow provide blank pressure-enthalpy charts for the following refrigerants:

R-22
R-32
R-134a
R-401A
R-402A
R-402B
R-404A
R-407A
R-410A
R-422B
R-438A
R-449A
R-452A
R-454B
R-463A
R-513A
R-514A
R-1234yf

Preview



Eighth Edition

PRESSURE ENTHALPY

WITHOUT TEARS

Eugene Silberstein, M.S., CMHE, BEAP

Over the past forty-five years, Eugene has been involved in all aspects of the HVACR industry and is presently serving as the National Programs Director at HVAC Excellence, a division of the ESCO Institute. Eugene has over thirty years of teaching experience and has taught at several private, secondary and postsecondary institutions. He can be seen at many national HVACR events, conventions and conferences where he, as a popular guest presenter, speaks on many different topics important to our industry.



Eugene earned his dual bachelor's degree from The City College of New York, where he studied electrical engineering, economics, operations management marketing, and finance. He earned his Master of Science degree from Stony Brook University, where he specialized in Energy and Environmental Systems, studying renewable and sustainable energy sources including wind, solar, geothermal, biomass and hydropower. He earned his Certified Master HVACR Educator (CMHE) credential in 2010 from HVAC Excellence. Eugene also carries the BEAP credential issued by ASHRAE, classifying him as a Building Energy Assessment Professional.

Eugene served as the subject matter expert and wrote the production scripts for dozens of educational videos directly relating to our industry in addition to co-authoring the number one HVACR textbook in the industry, "Refrigeration and Air Conditioning Technology", presently in its 10th Edition" published by Cengage Learning.

Other book credits include *Refrigeration and Air Conditioning Technology, 6th, 7th, 8th, and 9th Editions* (Cengage), *The Complete HVACR Lab Manual, 1st and 2nd Editions* (Cengage), *Residential Construction Academy: HVAC, 1st and 2nd Editions* (Cengage), *Heat Pumps, 1st and 2nd Editions* (Cengage), *Print Reading for HVAC, 1st and 2nd Editions*, (Goodheart-Willcox, 2021, 2025), *Psychrometrics Without Tears* (ESCO Institute, 2014), and *Electricity Theory and Applications* (Goodheart-Willcox, 2026).

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- Mastering the Art of Writing College Admissions Essays, 2025
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