2026

CONNECTICUT TECHNICAL EDUCATION AND CAREER SYSTEM

CTECS 9-12 HVAC Curriculum ©

CTECS 9TH – 12TH GRADE HVAC CURRICULUM ©

CTECS; CIARLEGLIO, PASQUALE (CO)

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Connecticut Technical Education and Career System

CTECS HVAC

Contents

CTECS HVAC

CTECS Instructional Model

CTECS uses the Marzano Compendium to guide research-based instructional strategies that differentiate learning and promote access, engagement, and success for all students. Teachers apply these strategies to support diverse learners (including multilingual learners, students with disabilities, and students with varied academic or technical backgrounds) through scaffolds, modeling, guided practice, and multiple ways to participate and show understanding. This approach ensures every student can work toward proficiency in the Priority Standards and the competencies outlined in the CTECS Vision of a Graduate.

Feedback	Content	Context
Providing and Communicating Clear Learning Goals 1. Providing scales and rubrics 2. Tracking student progress 3. Celebrating success **Using Assessments** 4. Using informal assessments of the whole class 5. Using formal assessments of individual students	**Conducting Direct Instruction Lessons** 6. Chunking content 7. Processing content 8. Recording and representing content **Conducting Practicing and Deepening Lessons** 9. Using structured practice sessions 10. Examining similarities and differences 11. Examining errors in reasoning **Conducting Knowledge Application Lessons** 12. Engaging students in cognitively complex tasks 13. Providing resources and guidance 14. Generating and defending claims **Using Strategies That Appear in All Types of Lessons** 15. Previewing strategies 16. Highlighting critical information 17. Reviewing content 18. Revising knowledge 19. Reflecting on learning 20. Assigning purposeful homework 21. Elaborating on information 22. Organizing students to interact	**Using Engagement Strategies** 23. Noticing and reacting when students are not engaged 24. Increasing response rates 25. Using physical movement 26. Maintaining a lively pace 27. Demonstrating intensity and enthusiasm 28. Presenting unusual information 29. Using friendly controversy 30. Using academic games 31. Providing opportunities for students to talk about themselves 32. Motivating and inspiring students **Implementing Rules and Procedures** 33. Establishing rules and procedures 34. Organizing the physical layout of the classroom 35. Demonstrating withitness 36. Acknowledging adherence to rules and procedures 37. Acknowledging lack of adherence to rules and procedures **Building Relationships** 38. Using verbal and nonverbal behaviors that indicate affection for students 39. Understanding students' backgrounds and interests 40. Displaying objectivity and control **Communicating High Expectations** 41. Demonstrating value and respect for reluctant learners 42. Asking in-depth questions of reluctant learners 43. Probing incorrect answers with reluctant learners

Curriculum Introduction

This curriculum document outlines the essential learning for this trade program and provides a clear structure for planning, instruction, and assessment. It includes the components required by NEASC Standard 2.2a, along with elements that reflect the unique nature of CTECS technical programs. The curriculum is organized to show what students learn in each course, how learning progresses across grade levels, and how instruction supports both technical skill development and the CTECS Vision of a Graduate.

Teachers should use this document to:

- Understand the overall structure and expectations of the course sequence
- Reference the Course Map to see the scope and sequence of Priority Standards and the alignment to District Summative Assessments (DSAs)
- Use the Priority Standards and Units of Study to guide daily, weekly, and cycle-based planning
- Integrate Big Ideas, Essential Questions, Skills/Learning Outcomes, vocabulary, and resources during lesson design
- Identify required safety, industry, and technical content expectations
- Plan and implement formative assessments to monitor progress and guide instruction
- Prepare students for the District Summative Assessments, ensuring alignment with the Course Map
- Maintain consistency of technical and professional practice instruction across campuses while adapting to student needs and industry-based opportunities

Curriculum Components

Course Map

A Course Map serves as the scope and sequence for this course by outlining the progression of instructional units and the standards that guide teaching and assessment. While each campus will have individual student needs, cycle schedules, and industry-based opportunities, all instructors are expected to teach the standards outlined in the Course Map. Using the Course Map below, teachers will intentionally plan learning experiences that prepare students to meet the identified standards within the designated assessment windows.

Priority Standards (Units of Study)

Priority Standards identify the most essential learning in the trade program. They reflect the core technical competencies, safety practices, and industry-aligned skills that require the greatest instructional focus and appear on program assessments. In CTE programs, each Priority Standard also functions as a Unit of Study, because it includes the required components such as big ideas, essential questions, content topics, and skills/learning outcomes aligned to assessments.

Vertical Alignment

Vertical alignment shows how Priority Standards and instructional expectations progress from grade to grade within the trade program. It provides a clear pathway of skill development, increasing complexity, and technical proficiency across the four-year sequence.

Learning Outcomes

Learning outcomes are what students will know (Concepts) and be able to do (Skills). Concepts identify the major content topics within the Priority Standard (Unit of Study). They appear in the left column of the Learning Outcomes table and follow a similar coding structure as the Priority Standard.

Skills are learning objectives that describe the measurable actions students must be able to perform to demonstrate proficiency. They appear in the right column of the Learning Outcomes table and show the progression of learning evidence in the Priority Standard.

Vocabulary

Essential vocabulary includes the technical and academic terms students must understand and use accurately to engage in trade-specific learning and demonstrate proficiency on assessments. Vocabulary is foundational to safety, technical precision, and industry communication, and should be a primary initial focus within each unit and taught explicitly through modeling, demonstration, and repeated application.

Resources

Resources include the tools, equipment, texts, materials, and digital tools that support learning within each unit and reflect industry standards.

Assessment Practices

Teachers use ongoing formative assessments—such as questioning, checks for understanding, performance demonstrations, reflections, and teacher observation—to monitor progress, guide instruction, and support all learners in mastering the Priority Standards.

Each program also includes District Summative Assessments (DSAs), which measure proficiency on the Priority Standards identified in the Course Map. DSAs provide consistent evidence of student learning across campuses and ensure alignment to industry expectations, safety requirements, and program outcomes. Teachers should reference the Course Map and Units of Study when planning instruction to ensure students have opportunities to practice and demonstrate the skills and knowledge assessed on the DSA.

CTECS HVAC

Proficiency Scale Alignment

Mastery by Design: Aligning to Marzano Proficiency Scales

To ensure every student reaches high-level learning, our curriculum utilizes **Marzano-aligned Proficiency Scales** directly embedded within each **Priority Standard**. Rather than a simple "pass/fail" metric, these scales provide a clear, consistent roadmap for growth, moving from foundational knowledge to complex application.

By placing these scales at the point of use within the curriculum, we bridge the gap between planning and instruction.

Why This Alignment Matters

- **Clarity of Expectation:** Teachers and students share a common language for what "Level 3.0" (Target Mastery) looks like versus "Level 4.0" (Exceeding the Standard).
- **Instructional Precision:** With scales linked to specific Priority Standards, you can instantly identify prerequisite skills (Level 2.0) to support struggling learners or provide enrichment for those ready to go beyond.
- **Scaffolded Success at Level 2:** To support foundational understanding, Level 2.0 includes explicitly aligned and tiered vocabulary required for each priority standard, ensuring students have the linguistic building blocks needed for mastery.
- **Data-Driven Feedback:** Grading becomes more objective and transparent, focusing on the evidence of learning rather than points earned.

The 4-Point Structure at a Glance

- 4.0: Exceeding: In-depth inferences and applications that go beyond what was taught.
- 3.0: The Target: Mastery of the specific Priority Standard as defined by the curriculum.
- 2.0: Foundational: Understanding of tiered vocabulary and basic processes related to the standard.
- 1.0: Emerging: Success with help or partial understanding of the 2.0 and 3.0 content.

CTECS HVAC

Integrated for Ease of Access: When you open a Priority Standard in your curriculum docs, the specific success criteria and required vocabulary are right there, ready for your daily lesson plan or assessment design.

A link to the CTECS Proficiency Scales aligned to this curriculum is located below:

CTECS HVAC Proficiency Scales

A more comprehensive guide to implementation can be found by clicking on the link below:

VANGUARD Trades PS Implementation Guide

CTECS HVAC Math Integration & Competency Crosswalks

To fully illustrate the rigorous mathematical foundations embedded within the ***CTECS HVAC curriculum***, we have developed a comprehensive integration guide. While the priority standards within this document include specific embedded examples of math applications, a more exhaustive resource is available for instructional use. This guide features detailed mathematics competency crosswalks designed to bridge technical skills with academic standards. You can access the complete ***CTECS HVAC Math Integration Guide*** on the Licensed Trades website or by clicking the link below:

Embedded Math

- **Point-of-Use Integration**: Each Priority Standard contains specific ***"Trade Math Crossover"*** sections that align mathematical concepts; such as: Gas Pipe Sizing, ladder ratios, and BTU Heat Load and Heat Loss Calculations; directly to the technical task at hand.
- **Marzano-Aligned Scales**: Every standard is linked to a Marzano-aligned Proficiency Scale, providing a clear 4-point roadmap from foundational vocabulary (Level 2.0) to target mastery (Level 3.0) and advanced application (Level 4.0).

- **Cross-Over Tables**: Detailed tables in the curriculum and ***appendix*** sections provide a crosswalk between technical skills and apprenticeship standards, ensuring students meet the requirements for CT-DOL related instruction.

Additional Resources

For those seeking more in-depth information, a more comprehensive guide to implementation and the full ***Math Integration Guide*** can be found on the **Licensed Trades website**

Access the HVAC Math Integration Guide

Access the Math/SAT/Code Crossover Guide

CTECS HVAC Philosophy

The ***CTECS HVAC course*** of studies is designed to create an appreciation of the industry and to develop entry-level skills within the ***HVAC*** construction trade. Opportunities to develop skills for personal use and to make a successful transition from school to the workplace or post-secondary institutions will be presented to students enrolled in this course.

The ***HVAC*** course is designed to provide Level I apprenticeship theory content within the trade. Practical experience will be gained within the school, through outside production experience, and through optional Work Based Learning, employed by a licensed ***HVAC*** contractor or wholesale company.

Program Description

Students enrolled in the ***CTECS Heating, Ventilation and Air Conditioning (HVAC)*** program will obtain instruction and demonstrate skills and knowledge in construction safety, measuring and blueprint reading, calculations of ductwork & heating systems with an emphasis on both heat loss and heat gain heating and cooling calculations. Students are also instructed on Domestic and Commercial Refrigeration systems, Gas, Oil Heating. Students in the HVAC program receive both on-site and off-campus jobsite learning opportunities simulating real-world applications.

CTECS HVAC

Students are trained in the installation and repair of refrigeration, heating, and cooling mechanical systems in both residential homes and commercial buildings. The systems that control indoor climate are constantly evolving to reflect technological advancements and environmental concerns.

In addition, students enrolled in the HVAC program will also obtain instruction in energy efficiency, environmental, renewable energy, as well as energy conservation practices.
A field that anticipates a high demand for skilled mechanics and technicians, the HVAC program ensures that students are skilled in the operation, design, installation, troubleshooting and repair of air conditioning, refrigeration, heating and ventilation equipment.

CTECS HVAC Goals

The ***HVAC*** Program will create an awareness of opportunities within the vast trade areas that comprise the HVAC Construction Industry. The program incorporates new developments and practices related to HVAC installation in residential, commercial and industrial construction.

Program Goals

As a result of education in the HVAC Program grades 9-12 students will:

- Identify, describe and apply health and safety regulations that apply to specific tasks and Jobsite Safety. Students must complete a safety credential program. Practice Shop and Jobsite Safety;
- Identify, describe and apply Environmental Protection Agency (EPA) and other environmental protection regulations that apply to specific tasks and jobs in the specific occupational area;
- Understand career opportunities in the HVAC industry;
- Study blueprints, design specifications, or manufacturers' recommendations to ascertain

the configuration of heating or cooling equipment components and to ensure the proper installation of components;

- Understand and apply joining methods for piping and sheet metal materials;
- Demonstrate safety in refrigerant handling following Environment Protection Agency (EPA) regulations;
- Describe, demonstrate and troubleshoot wiring of HVAC&R controls, motors, and circuits;
- Design, install and troubleshoot refrigeration components and systems;
- Design, install and service of Heating & Cooling Equipment and Systems (Oil, Gas, & Heat pump);
- Describe and demonstrate ventilation applications and forced-air duct systems;
- Perform blueprint reading, sketching and estimating according to code;
- Lay out full scale drawings of pipe systems, supports, or related equipment, according to blueprints;
- Demonstrate hand/power tool uses and operations;
- Install pipe systems to support alternative energy-fueled systems, such as geothermal and hybrid systems;
- Prepare cost estimates for clients

Program Standards

- Building Science Principles Certificate
- CT-DOL – Apprenticeship Related Instruction 720 Hours
- EPA Certification – Refrigerant Recovery/Recycling
- Fall Protection Certification
- Lockout Tagout Certification
- OSHA – 10, 30 Certification – CFR – 1926
- Roth Oil Tank Certification
- Ladder Safety Certification

CTECS HVAC

- CSST Gas Piping Certification
- Fluke Meter Certification
- Zoom Lock Certification

Program Locations in CT

CTECS HVAC:

1. Bristol Technical Education Center, **Bristol**
2. E.C. Goodwin Technical High School, **New Britain**
3. Emmett O'Brien Technical High School, **Ansonia**
4. H.C. Wilcox Technical High School, **Meriden**
5. Henry Abbott Technical High School, **Danbury**
6. Howell Cheney Technical High School, **Manchester**
7. J.M. Wright Technical High School, **Stamford**
8. Norwich Technical High School, **Norwich**
9. Platt Technical High School, **Milford**
10. Vinal Technical High School, **Middletown**
11. Windham Technical High School, **Willimantic**

CTECS HVAC

CT-DOL Program Approval

CONNECTICUT DEPARTMENT OF LABOR

The CTECS HVAC Curriculum is fully approved by the CT-DOL Office of Apprenticeship Training.

A CTECS HVAC graduate who *successfully completes* the program is entitled to 720 hours of related instruction training* towards a S-2 apprenticeship and all limited-licenses under the scope of the S-2.

(*Contingent upon student receiving OSHA 30 certification)

Curriculum Legend	
Bold	**Powered-Need to know**
Non-Bold	Nice to Know
Green Font	**Green Technology Alignment**
Red Font	**Common Core Technical Standards Alignment**
Blue Font	**Alignment to the CTECS Vision of a Graduate Standards**

CTECS Vision of a Graduate

The CTECS Vision of the Graduate: A Roadmap for Instructional Excellence

The ***CTECS Vision of the Graduate (VOG)*** represents the collective voice of our stakeholders, capturing the essential traits, attitudes, and skills our students need to excel both in our classrooms and in their future careers. More than just a list of aspirations, the VOG serves as a framework to help you deliver purposeful, high-quality instruction that prepares every student for the demands of the modern workforce.

How to Use This Document: To help you bridge the gap between curriculum standards and real-world application, we have integrated the VOG directly into your teaching tools:

- **Integrated Standards:** Each Priority Standard within this curriculum has been intentionally aligned with the CTECS VOG. To make these connections easy to identify at a glance, all VOG-aligned standards are denoted in ***blue font*** throughout this document.

- **Teacher Support Tools:** We have developed a comprehensive resource site to support your daily instruction. This hub provides the materials and strategies needed to bring these VOG traits to life in your shop or classroom.

Access your teaching resources here: [CTECS Licensed Trades VOG Resource Site]

The following page has a pictograph that depicts the six CTECS VOG traits we strive to adhere to:

CTECS VOG 1

CTECS HVAC Course Map

Grade 9, Semester 1

- 9-1: To have a general understanding of shop and work site safety
- 9-2: To have knowledge about the history of Heating, Air-conditioning and Refrigeration
- 9-3: To be able to use hand/power tools correctly
- 9-4: To have an awareness of the job opportunities available within the HVAC industry
- 9-5: Identify tools commonly used when working with copper tubing and their fastening\ sealing materials.

Grade 9, Semester 2

- 9-1: To have a general understanding of shop and work site safety
- 9-6: Introduction of the effects of heat energy and pressure on the properties of matter
- 9-7: Sheet metal basics
- 9-8: To have a basic understanding of electrical values and circuits including ohms law and rules for different electrical circuits.
- 9-9: To have a basic understanding of how electrical diagrams are use in HVAC
- 9-10: Comprehend how codes and their regulations affect the HVAC trade.
- End of Term DSA: (Please refer to DSA Study Guide for in-depth topics listed on the exam)

Grade 10, Semester 1

- 10-1: An understanding of the expected conduct at school, work site and how it relates to safety. (OSHA training)
- 10-2: Understand the application of and be able to interpret trade drawings
- 10-3: Knowledge of using the right fastener for the job, while using proper tool interaction for each fastener.
- 10-4: Advanced sheet metal.
- 10-5: To comprehend and to describe watts, ohms, volts, and amps using Ohms law
- 10-6: Knowledge and application of basic electricity, electrical circuits and AC electric motors
- 10-7: Know the use or function of typical electrical components found in HVAC systems.
- End of Term DSA: (Please refer to DSA Study Guide for in-depth topics listed on the exam)

Grade 10, Semester 2

- 10-8: Know the accepted types of pipe and piping practices.
- 10-9: To have a clear understanding of the effects of heat energy and pressure on the properties of matter
- 10-10: Understand the relationship of pressures and fluids at saturation temperatures.

- 10-11: To have a strong understanding the vapor compression refrigeration cycle.
- 10-12: Industry EPA standards for safety and environmental issues regarding refrigerant.
- End of Term DSA: (Please refer to DSA Study Guide for in-depth topics listed on the exam)

Grade 11, Semester 1

- 11-1: Comprehension of the conduct and safety expectations at the school/work site.
- 11-2: Application of knowledge of basic electricity, electrical circuits and AC electric motors
- 11-3: Have an understanding the use of building codes and manufacturers' installation instructions on current production jobs
- 11-4: Understand how to calculate total heat gain/loss for the proper sizing of heating\cooling equipment.
- 11-5: Understanding of airflow principles and design of air handling equipment.
- End of Term DSA: (Please refer to DSA Study Guide for in-depth topics listed on the exam)

Grade 11, Semester 2

- 11-6: Have the understanding of how to safely work with fuel gases while comprehending industry environmental issues regarding storage
- 11-7: Have the knowledge and the ability to conduct a start-up on gas heating systems and combustion
- 11-8 Have the knowledge how to systematically troubleshoot and to service a Gas system

- 11-9: Have the understanding of how to safely handle refrigerants, while comprehending industry environmental issues regarding refrigerant.
- 11-10: Have a comprehensible understanding of the refrigeration cycle and superheat, sub-cooling, and coil temperature differences.
- End of Term DSA: (Please refer to DSA Study Guide for in-depth topics listed on the exam)

Grade 12, Semester 1

- 12-1: Have the understanding of how to safely work with fuel oil while comprehending industry environmental issues regarding storage and combustion.
- 12-2: Become acquainted with various contemporary oil heating appliances.
- 12-3: Have the knowledge and the ability to conduct a start-up on oil heating systems.
- 12-4: Have the knowledge how to systematically troubleshoot and service an Oil system.
- 12-5: Industry EPA standards for safety and environmental issues regarding refrigerant.
- End of Term DSA: (Please refer to DSA Study Guide for in-depth topics listed on the exam)

Grade 12, Semester 2

- 12-6: Know the mechanical refrigeration cycle and be able to troubleshoot problems.
- 12.7: Have an understanding of startup and testing procedures of an air-conditioning system
- 12-8: Have an understanding of the theory of a heat pump systems operation and its functioning ability
- 12-9: Have the knowledge how to systematically troubleshoot so to service an air conditioning
- 12-10: Become acquainted with Hydronic heating systems

CTECS HVAC

- 12-11: Have an understanding of startup and testing procedures of a Hydronic system
- End of Term DSA: (Please refer to DSA Study Guide for in-depth topics listed on the exam)

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CONNECTICUT TECHNICAL EDUCATION AND CAREER SYSTEM

HVAC

Grade 9

Grade 9 Curriculum

Priority Standard 9-1: Shop and work site safety.	
Big Idea(s): 1. Safety practices build the foundation of a successful HVAC career by protecting workers and promoting efficiency through awareness, responsibility, and routine. 2. The ability to earn a living in our trade is based upon safe work practices. Safety needs to be a habit and a consideration throughout daily living as well as in the work environment. 3. Safety is not just a set of rules but a continuous practice required to protect oneself and others in a high-risk environment.	
Essential Question(s): 1. How do safety protocols in a workshop or worksite help prevent accidents, and what role do individuals play in maintaining a safe environment? 2. Why do you think that OSHA training is a requirement in order to be employed in the construction trade?	
Learning Outcomes	
Students will know:	*As evidenced by:*
9-1.A Personal Protective Equipment • Work Boots/Safety Shoe • Proper fit • Ear protection • Safety Glasses • Gloves • Hard hat • OSHA	1. Provide reasons with examples for use of each as written assessment. 2. Daily assessment of personal safety during lab work. 3. Students are wearing appropriate proper fitting clothing. Including Uniform hard hat, safety glasses, hearing protection, safety shoes, gloves, etc. 4. Remove jewelry. 5. Score 100% on the written Safety Test. 6. Explain OSHA.

9-1.B Hazards in the Workplace • **Using torches** • **Cutting wood and metal with saws** • **Cutting sheet metal** • **Drilling holes** • **Throwing instead of carrying tool** • **Carrying heavy objects**	**1. Recognize situations that are unsafe in the shop for a given situation/scenario.** **2. Identify work areas that have potential safety risks.** **3. Explain possible consequences of talking to someone while using tools or throwing an object.** **4. Identify the cause of injuries.** **5. Identify fire alarms, extinguishers, blankets, eye wash stations, and power shut-off locations.** **6. Explain the dangers of coming in contact with blood pathogens.**
9-1.C Substance Abuse • **Alcohol** • **Over the counter and prescribed medications** • **Illegal drugs**	**1. Analyze how impaired thought and coordination can cause serious injury or death of self or others around them.**
9-1.D Hardware and Materials • **Screws** • **Nails** • **Hinges**	**1. Demonstrate proper use of hardware items.** **2. Demonstrate proper disposal and recycling of items such as sharp materials.**
9-1.E Fire safety • **Protecting against fire** • **Fire classifications** • **Fire extinguisher use**	**1. Identify different classifications of fire extinguishers.** **2. Explain proper use of a fire extinguisher.**
9-1.F Work habits • **Neatness** • **Thoroughness** • **Systematic procedures** • **Working patiently**	**1. Explain and demonstrate work habits including, neatness, thoroughness, systematic procedures and patience.**
9-1.G Environmental Safety • **Greenhouse gases** • **Ozone layer** • **Chemical disposal**	**1. Explain the need to protect the environment when working with and disposing of HVAC equipment.**
9-1.H Live Work Precautions. • **Electrocution**	**1. Demonstrate safe meter use.**

• **Moving parts**	**2. Demonstrate keeping a safe distance when working near moving components.** **3. Perform Lock out/Tag out procedure.**
9-1.I Storage and Handling of cylinders • **Danger of tanks falling** • **Oil use around oxygen** • **Pressure regulators** • **Storage**	**1. Demonstrate proper handling of pressurized vessels.** **2. Demonstrate proper storage of pressurized vessels.**
9-1.J Sheet Metal hop Safety. • **How to work safely in the sheet metal shop with others**	**1. Demonstrate fabricating sheet metal projects safely.** **2. Explain shop safety procedures and concerns with peers and others about safety when working with sheet metal.** **3. Identify safety hazards in the sheet metal shop.**

Link to Proficiency Scale 9-1

Tiered Vocab- HVAC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:

- **Tier 1:** Common, everyday words (Basic communication).
- **Tier 2:** High-frequency academic words (Used across various subjects/trades).
- **Tier 3:** Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Work Boots • Proper fit • Ear protection • Safety Glasses • Gloves • Personal Protective Equipment • (PPE) • Signal Word • Lockout/Tagout • Air-Purifying Respirator • Confined Space Hazard	• Fire extinguisher • Neatness • Electrocution • Hazard Communication Standard • (HCS) • Pictogram • Hazard • Safety Data Sheet • (SDS) • Stationary Refrigerant Detector • Supplied-Air Respirator	• OSHA • PPE • MSD • Ozone Layer • Globally Harmonized System (GHS) • ASHRAE Standard 34

• Occupational Safety and Health • Act (OSHA)		

Trade Math Crossover: (VOG- Problem Solver)

Focus: Risk mitigation and the geometry of equipment stability.

- **The 4:1 Ladder Ratio:** According to safety standards, for every 4 feet of vertical height, the base of the ladder must be 1 foot away from the wall.
  - **Math Example:** If a technician must extend a ladder to reach a 20-foot roof line, calculate the required distance the base of the ladder should be from the building to maintain a safe 4:1 ratio.
- **Pressure Vessel Safety:** Students must demonstrate the proper handling and storage of high-pressure cylinders (Oxygen, Nitrogen, Acetylene).
  - **Math Example:** If a Nitrogen tank has a pressure of 2,000 PSI at 70°F, students explore how pressure increases with temperature (Charles's Law) to understand why tanks must be stored away from heat sources to prevent them from becoming "projectiles"

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599
Chapter 3. Safety

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545
Section 1, Chapter 2.

Basic Principles for Construction, 4th Edition (Residential Construction Academy) 4th Edition
ISBN-13: 978-1-3050-8862-7
Chapter 3. Job Safety

OSHA.Gov:
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

OSHA 30: A0099

VOG Portfolio Collection Examples

VOG – A Critical Thinker

- **Example**: Students will have the ability to develop a Fire Evacuation plan with proper egress and exits

VOG Alignment: Critical Thinker & Problem Solver.

- **Example:** Project: Shop Safety Audit & Evacuation Map: Description: Students work in teams to identify potential hazards in the HVAC shop (e.g., improper cylinder storage or blocked egress). They must create a professional fire evacuation plan and a safety checklist for personal protective equipment (PPE).

VOG Trait: An Effective Communicator

- **Example:** During a simulated lockdown or fire drill, the student clearly and calmly directs peers to the designated evacuation routes and identifies the nearest fire extinguisher and power shut-off locations.

Priority Standard 9-2: History of Heating, Air-Conditioning, and Refrigeration	
Big Idea(s): **1. Understanding the evolution of HVAC systems helps students appreciate the technological progress that improves health, comfort, and energy use in modern life.**	
Essential Question(s): **1. How have advancements in heating, air conditioning, and refrigeration technologies shaped modern life, and what were the key innovations that made these systems possible?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
9-2.A History of heating systems. • **Fire/Fireplace** • **Wood/coal stoves** • **Wood/coal boilers/furnace** • **Oil/gas boilers/furnace** • **Electric resistance heaters** • **High efficiency boiler and furnaces** • **Passive solar** • **Active solar** • **Combination systems hydro air boiler with blower**	**1. Explain the history of heating systems “from fireplaces to hydro air”.** **2. Identify heating systems, water, air, oil, gas, electric resistance, heat pumps, solar.**
9-2.B Air-conditioning and Refrigeration History • **Air circulation for building cooling** • **Underground food storage** • **Ice used to absorb heat** • **Mechanical cooling system**	**1. Compare and contrast historical events of air-conditioning and refrigeration** **2. Construct a timeline of key historical events of refrigeration** **3. Giving examples of the effects on society since the development of air conditioning.**

9-2.C Air-conditioning and refrigeration and define their differences.	1. **Explain the 6 elements of a complete air conditioning system, heat, cool, humidify, dehumidify, clean air, move air** 2. **Explain refrigeration as used for retarding bacterial growth.**
9-2.D Types of AC Systems.	1. **Identify package and split air conditioning systems**
9-2.E Air-conditioning Human Comfort	1. **Explain the history of air conditioning including needs beyond human requirements such as temperature and humidity standards for human comfort (Effective Communicator)**
9-2.F Trade Associations in the HVAC Trades	1. **Identify different trade associations within Connecticut and United States, i.e., RSES, ACCA, ARI, CHCCA, ASHRAE** 2. **Provide education, keeping workers up to date on industry and work standards**

Link to Proficiency Scale 9-2

Tiered Vocab- HVAC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:

- **Tier 1:** Common, everyday words (Basic communication).
- **Tier 2:** High-frequency academic words (Used across various subjects/trades).
- **Tier 3:** Low-frequency, domain-specific technical terms (The “Language of the Trade”).

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• HVAC/R • Ladder Diagram • Pictorial Diagram • Mechanical Skill • Mental Skill • Physical Skill	• Technician • Service Technician • Installer • Parts Clerk	• Building Engineer • Technical Training Instructor • Building Engineer • Energy Auditor • Business Owner

Trade Math Crossover:

1. The Industrial Revolution and Ice Harvesting

Before mechanical refrigeration, cooling was measured by the weight of natural ice harvested from lakes. This is where the term "Ton of Refrigeration" originates.

- **The Data:** 1 Ton of refrigeration is defined as the amount of heat required to melt 2,000 lbs. (1 ton) of ice in 24 hours. The "Latent Heat of Fusion" for ice is 144 BTUs per pound.
- **The Math:** Calculate the total BTUs required to melt one ton of ice (2,000 lbs. times 144 BTUs/lb.). Then, divide that by 24 hours to determine how many BTUs per hour (BTU/h) equal exactly "1 Ton."
- **Historical Application:** If an 1850s brewery required 100,000 BTUs of cooling per hour, how many literal tons of ice did they need to harvest and store to keep the beer cold for one full day?

2. The Carrier Revolution (1902)

Willis Carrier invented the first modern air conditioner to control humidity in a printing plant. He discovered that cooling air also "dehumidifies" it.

- **The Data:** For every 20°F drop in air temperature, the air’s capacity to hold water vapor is roughly cut in half.
- **The Math:** If the air in a 1902 printing plant starts at 90°F with 100% relative humidity (holding approximately 15 grains of water per cubic foot), and Carrier’s machine cools it to 70°F, how many grains of water are removed from every cubic foot of air?
- **Historical Application:** If the plant has a volume of 50,000 cubic feet, calculate the total weight of water removed from the air in one hour. (Note: 7,000 grains = 1 pound).

3. The Evolution of Efficiency (SEER Ratings)

In the mid-20th century, efficiency wasn't a priority. Today, the Seasonal Energy Efficiency Ratio (SEER) is the industry standard.

- **The Comparison:** A standard air conditioner from 1970 had an average SEER of 6. A modern high-efficiency unit has a SEER of 18.
- **The Math:** Efficiency is calculated as BTUs / Watts. If both units produce 36,000 BTUs (3 Tons) of cooling:
  - Calculate the Watts used by the 1970 unit (36,000 / 6).

  - Calculate the Watts used by the 2026 unit (36,000 / 18).
- **Historical Application:** Calculate the percentage of energy reduction achieved by the industry over the last 50 years.

4. Refrigerant Timeline and Global Warming Potential (GWP)

The industry has moved from toxic gases (Ammonia) to CFCs (R-12), then HCFCs (R-22), and now to low-GWP refrigerants.

- **The Data:** * R-12 (used in 1950s cars) has a GWP of 10,900.
  - R-22 (used in 1990s houses) has a GWP of 1,810.
  - R-454B (modern 2026 standard) has a GWP of 466.
- **The Math:** If a 1950s commercial chiller leaked 50 lbs. of R-12, and a modern chiller leaks 50 lbs. of R-454B, calculate the "Carbon Equivalent" for both (Lbs. times GWP).
- **Historical Application:** How many times more environmentally damaging was a single R-12 leak compared to a modern leak?

5. The Scaling of Comfort (BTUs per Square Foot)

Historically, homes were built with high ceilings and transoms for natural airflow. As HVAC became standard, home design changed.

- **The Calculation:** Historically, we estimate 1 Ton of cooling for every 500–600 square feet of living space.
- **The Scenario:** A 1920s Sears Kit House has 1,800 square feet.
- **The Math:** Based on the 1 Ton per 600 sq. ft. rule, how many BTUs of cooling would this historic home require if it were retrofitted with modern AC today? (1 Ton = 12,000 BTUs).

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 1. Careers in HVAC

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Introduction

Basic Principles for Construction, 4th Edition (Residential Construction Academy) 4th Edition
ISBN-13: 978-1-3050-8862-7

- Section 1 Chapter 1 working in industry

OSHA.Gov:
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

Refrigeration Fundamentals A0781

VOG Portfolio Collection Examples

VOG Trait- A Problem Solver.

- **Example**: Students will be able to take a Delta-t measurement across an evaporator coil and record the information accurately.
- **Example**: When studying the history of central heating, a student identifies why early "gravity" furnaces were inefficient compared to modern forced-air systems. They propose a hypothetical "retro-fit" solution for an old building that maintains historical integrity while improving energy efficiency.

VOG Trait: Effective Communicator.

- **Example: The Evolution of Comfort Timeline:** Description: Students research and present a timeline of heating and cooling, from open fireplaces to modern high-efficiency heat pumps, explaining how these advancements impacted human health and society.
- **Example:** Using technical terminology correctly, a student explains to a peer why the move from harmful CFC refrigerants (like R-12) to modern HFOs was a necessary communication between scientists and trade professionals to protect the ozone layer.

VOG Trait: A Critical Thinker

- **Example:** A student compares ancient Egyptian "evaporative cooling" (wet reeds in windows) to a modern swamp cooler. They analyze how the basic laws of thermodynamics—the same ones used thousands of years ago—still govern the design of cutting-edge HVAC equipment today.
- **Example:** The student evaluates the "Great Transition" from natural ice harvesting to mechanical refrigeration (pioneered by John Gorrie), explaining how this shift fundamentally changed human health and global food supply chains.

Priority Standard 9-3: Hand/Power Tools	
Big Idea(s): 1. **Using the right tool for the job improves quality, efficiency, and safety, and demonstrates the professionalism expected in the HVAC trade.**	
Essential Question(s): 1. **Why is it that skilled craftspeople get paid more?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
9-3.A Hand and Power tools • **Hand Drill** • **Drill press** • **Band saw** • **Reciprocating saw** • **Circular saw** • **all sizes of standard screwdriver** • **all sizes of Phillip screwdriver** • **combination wrenches** • **Adjustable wrench** • **Needle nose Pliers** • **Lineman pliers** • **Diagonal pliers** • **Pipe pliers** • **Crimper/stripers**	1. **Label hand/power tools.** 2. **Verbally identify the correct application.**
9-3.B Power Tool Safety • **Hand Drill** • **Drill press** • **Band saw**	1. **Demonstrate the proper and safe use of listed power tools.** 2. **Select the proper tool for given projects.**

• **Reciprocating saw** • **Circular saw**	3. **Pass a written exam on safety of power tools.**
9-3.C Proper Power Tool Selection • **All sizes of standard screwdriver** • **All sizes of Phillip screwdriver** • **Combination wrenches** • **Adjustable wrench** • **Needle nose Pliers** • **Lineman pliers** • **Diagonal pliers** • **Pipe pliers** • **Crimper/stripers**	1. **Demonstrate the proper and safe use of listed hand tools.** 2. **Select the proper tool for given projects.** 3. **Pass a written exam on safety of hand tools** 4. **Demonstrate safe and proper use of required tools and equipment used in the solar trades, (Reference NABCEP 1.2)**
9-3.D Stationary HVAC Equipment. • **Pittsburg** • **Foot operated shear** • **Bending break** • **Box, pan, finger break** • **Roller**	1. **Demonstrate the proper and safe use of listed manufacturing equipment** 2. **Select the proper tool for given projects** 3. **Pass a written exam on safety of large manufacturing equipment**
9-3.E Maintenance of Equipment • **Hand oiler** • **Grease gun** • **Spray lubricants**	1. **Demonstrate the use of lubricating tools commonly used in HVAC such as grease gun and spray lubricants.**
9-3.F Fasteners • **Nails** • **Screws** • **Bolts** • **Nuts** • **Lags**	1. **Identify fasteners commonly used in HVAC**

Link to Proficiency Scale 9-3

Tiered Vocab- HVAC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:

- Tier 1: Common, everyday words (Basic communication).
- Tier 2: High-frequency academic words (Used across various subjects/trades).
- Tier 3: Low-frequency, domain-specific technical terms (The “Language of the Trade”).

Tier 1 (Everyday)	**Tier 2 (Academic)**	**Tier 3 (Technical/Trade)**

CTECS HVAC

• Adjustable wrench • Box end wrench • Combination pliers (slip-joint) • Diagonal pliers • Double-cut file • File • Hacksaw • Hammer • Hex key • Lineman's pliers • Screwdriver • Cordless drill	• Open End Wrench • Box End Wrench • Combination Wrench • Adjustable Wrench • Pump Pliers • Diagonal Cutting Pliers • Adjustable Pliers • Nut Drivers • Straight Blade Screwdriver • Fearson Screwdriver • Nail Hammer • Hacksaw • Drill Bit • Snips • Struck Tools • level(orientation)level(tool) • Center punch • Cold chisel • Flare nut wrench • Mallet • Socket wrench • Twist drill bit • Vise • Sawzall • Circular saw	• Flare Nut Wrench • Allen Wrench • Socket Wrench • Lineman's Pliers • Locking Pliers • Torx Bit Driver • Ball Pein Hammer • Setting Hammer • Hole Saw • Aviation Snips • Masonry Drill Bit • Chisel • Punches • Cold Chisels • Abrasives • Cleaning solvent • Manometer • Refrigeration service valve wrench • Thermometer • Temperature analyzer • Right angle drill • Hammer drill

Trade Math Crossover:

Focus: Precision measurement and material allowances.

- **Copper Tubing Circumference:** Students must identify tools for working with copper and understand their mechanical operation.
  - **Math Example:** For a piece of 1/2-inch Type L copper pipe with an outside diameter (OD) of 0.625 inches, calculate the total distance (circumference) a tubing cutter wheel travels in one complete revolution (C = π Times d).

- **Cutting and Kerf Loss:** When using a hacksaw, the "kerf" (width of the saw blade) removes material.
    - **Math Example:** If a student needs to cut three 12-inch pieces of copper from a larger pipe using a blade with a 1/16-inch kerf, calculate the total length of pipe consumed, including the material lost to the three cuts.

- **Selection:** Hammers come in different weights for different types of nailing. A 16oz. hammer is used for general use. A 28 oz. hammer is used for heavy duty nailing. What is the difference in weight are they?

- **Decimal Conversions:** Converting 1/16” increments on a tape measure to decimals for precise drilling (e.g., 5/16” = 0.3125”).

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599
- Chapter 2. Hand tools

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545
- Section 3 Chapter 7 Tools and supplies

Basic Principles for Construction, 4th Edition (Residential Construction Academy) 4th Edition
ISBN-13: 978-1-3050-8862-7
- Section 4 Chapter 14 Hand tools
- Section 4 Chapter 15 Power tools
- Section 4 Chapter 16 Fasteners

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5
- Unit 5 Tools & equipment
- Unit 6 Fasteners

OSHA.Gov:
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0781 Refrigeration Fundamentals –B- Tools

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** Before starting a task, the student evaluates their tool kit to select the most efficient tool for the job (e.g., choosing a tubing cutter over a hacksaw for a precise copper cut) and explains why that choice prevents material waste and ensures system integrity.

VOG Trait: Work Ready

- **Example:** After completing a project, the student demonstrates professional work habits by cleaning, servicing, and returning all tools to their designated locations, maintaining an organized environment as expected by a professional employer.
- **Example:** Students will be able to identify the correct snips for cutting sheet metal for a customer's project.

Priority Standard 9-4: Job opportunities available within the HVAC industry	
Big Idea(s): **1. The HVAC field offers a wide range of career paths, and exploring these options helps students align their interests with industry demand and emerging technologies.**	
Essential Question(s): **1. What types of jobs are available in the HVAC industry, and how do these careers contribute to our daily lives and the environment?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
9-4.A Job opportunities in the HVAC industry. • **Electrical** • **Plumbing** • **Heating** • **Air Conditioning** • **Refrigeration** • **Sheet Metal** • **Residential** • **Commercial** • **Industrial** • **Service** • **Installation** • **Maintenance**	**1. Explain careers that are included in the HVAC trade.** **2. Discuss opportunities for graduates of HVAC.** **3. Develop a list of job opportunities within the field.** **4. Prepare a report on career opportunities in the total comfort industry.** **5. Explain differences between Industrial, Commercial, and residential** **6. Develop an understanding of apprenticeship and how it differs between trades and the purpose of its existence.** **7. Identify installation, service, maintenance jobs.** **8. Identify upcoming changes in the industry.** **9. Demonstrated Knowledge of *GREEN TECHNOLOGIES* and their impact on jobs in HVAC.**
9-4.B Job Selection Methods • **Most enjoyable tasks**	**1. Create a personal skill portfolio and predict/forecast job opportunities.**

• **Easiest task to learn** • **Greatest need** • **Highest earning potential**	
9-4.C HVAC licensing in Connecticut • **S2** • **D2** • **B2** • **SM 2** • **S10**	**1. List different licenses.** **2. Explain differences in licenses.**
9-4.D Customer Expectations as it pertains to Solar Thermal Installations. (Reference NABCEP 11.7-11.13)	**1. Demonstrate to the owner operation and functionality of system** **2. Demonstrate to the owner start-up and shut-down procedures for system** **3. Demonstrate to owner simple maintenance and diagnostic procedures** **4. Identify for owner all markings and labels for system service and owner interaction** **5. Identify for owner safety issues associated with operation and maintenance of system** **6. Complete and transfer documentation package to system owner/operators** **7. Review system/component warranties and requirements with owner**

Link to Proficiency Scale 9-4

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- Tier 3: Low-frequency, domain-specific technical terms (The “Language of the Trade”).

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Installer	• Mechanical Skill	• Service Technician

Trade Math Crossover:

1. Residential Service vs. Commercial Construction (Labor Rates)

A 9th-grade student is exploring the difference between "service" work and "new construction" work.

- **The Scenario:** A Residential Service Technician is paid **$22/hour** but receives a **5% commission** on all parts sold. A Commercial Construction Pipefitter is paid a flat "prevailing wage" of **$38/hour**.
- **The Math:** If the Service Tech works 40 hours and sells $8,000 worth of equipment in a week, calculate their total gross pay. Compare this to the Construction Pipefitter's 40-hour gross pay.
- **Career Reflection:** Which career path provided a higher weekly paycheck in this scenario?

2. The Value of Specialization (TAB Technician)

Testing, Adjusting, and Balancing (TAB) is a specialized HVAC career that focuses on airflow and water flow.

- **The Data:** A TAB Technician is tasked with balancing a rooftop unit that is supposed to deliver **2,000 CFM** (Cubic Feet per Minute) of air. There are 10 supply registers in the building.
- **The Math:** If the technician measures the airflow at each register and finds they are each only putting out **165 CFM**, calculate the total airflow currently being delivered.
- **The Problem:** What percentage of the design airflow (2,000 CFM) is the system currently missing? This calculation is the core of a TAB technician's daily job.

3. HVAC Sales and Estimating

An Inside Sales Representative or Estimator must calculate costs to provide customers with accurate quotes.

- **The Scenario:** A customer wants to replace an old furnace. The furnace costs the company **$1,400**. The company requires a **25% "gross profit margin"** on all equipment sales to cover the salesperson's salary and office overhead.
- **The Math:** Use the margin formula (Cost / (1 - 0.25) to calculate the price the salesperson must quote the customer.

- **The Comparison:** If the salesperson mistakenly just added 25% "markup" to the cost (1,400 \times 1.25), how much money would the company lose compared to the required 25% margin?

4. Facility Maintenance (The Cost of In-House Staff)

Large hospitals and universities hire in-house HVAC Maintenance Technicians rather than calling outside contractors.

- **The Scenario:** An outside contractor charges **$125/hour** to fix a chiller. A hospital's "in-house" technician earns **$32/hour**, but their total "burdened" cost (including insurance and retirement) is **1.4 times** their hourly wage.
- **The Math:** Calculate the hourly cost to the hospital for their in-house technician.
- **The ROI:** If the in-house technician spends 200 hours a year on repairs that would have otherwise gone to the outside contractor, how much money does the hospital save annually by employing their own staff?

5. Union Apprenticeship Progression

Many HVAC students enter a 5-year Union Apprenticeship. Pay increases are usually a percentage of the "Journeyman Rate."

- **The Data:** A Journeyman HVAC Mechanic makes **$45.00/hour**.
  - 1st Year Apprentice: 40% of Journeyman Rate
  - 3rd Year Apprentice: 60% of Journeyman Rate
  - 5th Year Apprentice: 85% of Journeyman Rate
- **The Math:** Calculate the hourly wage for a student at each of these three steps.
- **The Growth:** If a student works 2,000 hours in their 1st year and 2,000 hours in their 5th year, what is the total annual dollar increase in their salary from the start to the end of the apprenticeship?

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 1 Careers In HVAC

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 1 Careers & certifications

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Introduction section

Basic Principles for Construction, 4th Edition (Residential Construction Academy) 4thEdition ISBN-13: 978-1-3050-8862-7

- Chapter 3 Introduction to Green Building

OSHA.Gov:
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0729 International mechanical Code

VOG Portfolio Collection Examples

VOG Trait: An Effective Communicator

- **Example:** A student conducts an informational interview with a local HVAC professional (e.g., an installer, service technician, or business owner) and presents a summary of the daily responsibilities and required certifications for that specific role to their classmates.
- **Example:** Using trade-specific vocabulary, a student explains the different "career ladders" within the industry, such as the transition from a **Parts Clerk** to a **Service Technician** and eventually a **Building Engineer** or **Business Owner**

VOG Trait: A Critical Thinker

- **Example:** A student analyzes current labor market data to compare the long-term career outlook and salary potential of residential HVAC technicians versus commercial/industrial refrigeration specialists.
- **Example:** The student evaluates the impact of "Smart" technology and energy-efficiency regulations on future job roles, identifying why a modern technician must be both a mechanical expert and technologically fluent.

VOG Trait: Work Ready

- **Example:** A student begins their **Student Competency Checklist** by identifying which specific HVAC career paths (e.g., sheet metal fabrication, hydronics, or solar thermal) align with their personal strengths and interests.
- **Example:** The student researches the specific **CT-DOL apprenticeship requirements** (720 hours of related instruction) and develops a personal "roadmap" for how they will achieve these hours during their four years at CTECS.
- **Example:** Students that take part in our HVAC/R program recognize that there are many career paths to choose from in the HVAC/R field.

Priority Standard 9-5: Identify tools commonly used when working with copper tubing and their fastening/sealing materials.	
Big Idea(s): 1. **Mastering copper tubing tools and joining techniques is essential for producing durable, leak-free connections in both traditional and green HVAC systems.**	
Essential Question (s): 1. **What tools and materials are commonly used to work with copper tubing, and how do they help create secure, leak-proof connections in plumbing or HVAC systems?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
9-5.A Tubing and piping used in the HVAC/R industry	1. **Identify ACR size verse nominal size.** 2. **Identify K,L,M, and DW pipe.** 3. **Identify purpose and application of each type of pipe.**
9-5.B Tubing tools that are associated with copper tubing.	1. **Demonstrate safe practices using tools commonly used when working with copper tubing.** 2. **Take a written test on tools used with working piping.** 3. **Demonstrate proper use of acetylene and oxygen/acetylene torch.**
9-5.C Soldering and brazing alloys used in HVAC/R industry and describe their purpose.	1. **Distinguish differences between soldering filler metals i.e., 50/50, 95/5 etc.** 2. **Discuss percent of silver content importance.**

	3. Reviewing percentage of silver content and its importance. **4. Identify brazing filler metals and melting temperatures.**
9-5.D Several types of fittings and describe and analyze their purpose.	**1. Identify long radius verse short radius elbows** **2. Shown tee sizing i.e., ¾ x ¾ x ¾ or ¾ x ¾ x ½ tee with reducing branch**
9-5.E Types of torches used in the HVAC/R industry.	**1. Explain the appropriate use of each method in a written assessment.**
9-5.F Applications of soldering and brazing alloy that will be used with copper joints.	**1. Demonstrate safe practices using tools commonly used when working with copper tubing**

Link to Proficiency Scale 9-5

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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	**Tier 2 (Academic)**	**Tier 3 (Technical/Trade)**
• Tubing • Pipe • Annealed • Tubing Cutter • Wrought Fittings • Flare Fitting • Bending spring • Tubing bender • Neutral flame • Oxyacetylene torch • Soldering • Solvent • Welding	• Type K Tubing • Type L Tubing • Type M Tubing • Tubing Reamer • Tubing Bender • Swaging • ABS (acrylonitrile- butadiene-styrene) • annealing • CPVC (chlorinated polyvinyl chl oride) • double flare • PVC (polyvinyl chloride) • chloride • Street fitting • Capillary action	• ACR Tubing • Union Fitting • Mechanical Fittings • Soldering • Brazing • Carburizing • Flame • Purging • Hard Drawn Copper • Flux • Outside Diameter (OD) • Inside Diameter (ID) • Oxidizing flame

	• Single flare	

Trade Math Crossover:

1. Tubing Cutter: Circumference and Travel: A tubing cutter must travel in a perfect circle around the pipe. If the wheel is dull or the tool is misaligned, it will "thread" (create a spiral) instead of a cut.

- **The Data:** A student is cutting a piece of 7/8" OD (Outside Diameter) AC&R copper tubing.
- **The Math:** Calculate the total distance the cutting wheel travels in one complete revolution around the pipe (C = π times d).
- **The Depth Challenge:** If the copper wall is 0.045 inches thick and each half-turn of the cutter handle advances the blade 0.003 inches, how many full revolutions are needed to cut through the pipe?

2. Flaring Tools: The 1/3 Projection Rule: When creating a flare joint, the copper must stick out above the flaring block a specific distance (usually about 1/3 the thickness of the flare nut's shoulder) to ensure there is enough material to seal.

- **The Scenario:** A student is flaring 3/8" copper tubing. The manufacturer recommends the pipe protrude 1/16" (0.0625") above the block.
- **The Math:** If the student accidentally lets the pipe protrude 1/8", calculate the percentage of "over-extension." Use your knowledge of geometry to explain why a flare that is too large will prevent the flare nut from threading properly onto the fitting.

3. Swaging: Depth and Friction: Swaging involves expanding the end of one pipe so another pipe of the same size can slip inside it, creating a "cup" for brazing.

- **The Rule of Thumb:** The depth of the swage (the cup) should be equal to the diameter of the pipe.
- **The Math:** If a student is swaging 5/8" copper tubing, how deep (in inches) must the swage tool penetrate the pipe?

- **Material Science:** If the swage tool expands the diameter of the pipe by 0.040 inches on all sides, calculate the new total circumference of the expanded section.

4. Reaming and Material Removal: After cutting copper, a reamer is used to remove the internal "burr" that can cause turbulence and pressure drop in the refrigerant line.

- **The Scenario:** A 1/2" ID (Inside Diameter) pipe has a burr that reduces the opening's diameter to 0.44 inches.
- **The Math:** Calculate the surface area of the "clean" opening ($A = \pi r^2$) versus the "burred" opening. What percentage of the flow area is restricted by the burr before the student uses the reaming tool?

5. Bending Radius (The Spring Bender): When using a spring bender or a mechanical lever bender, the "radius" of the bend is critical to prevent the pipe from kinking or collapsing.

- **The Data:** A mechanical bender for 1/2" copper has a 2-inch radius.
- **The Math:** Calculate the total length of copper pipe used to create a perfect 90-degree bend (one-quarter of a circle's circumference).
- **Formula:** Length = 1/4 times (2 times π times Radius).

6. ID/OD: When measuring ACR copper tubing the technician measurers 7/16ths inside diameter (ID). What should the outside measurement (OD) be?

7. Fitting Allowance: Calculating the exact length of pipe to cut by subtracting the “fitting allowance” from the center-to-center measurement.

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599
- Chapter 4,5,6,7 Piping Practices

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545
- Chapter 8 Tubing

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 7 Tubing & piping

OSHA.Gov:
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A2113 Brazing, cutting metals – A- Brazing, welding, and soldering

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** When preparing to join two sections of ACR (Air Conditioning & Refrigeration) tubing, a student evaluates whether to use a **tubing cutter** or a **close-quarters cutter** based on the available space. They explain how using a dull wheel or applying too much pressure can create a "burr" that restricts refrigerant flow, showing an understanding of how tool maintenance affects system performance.
- **Example:** The student distinguishes between **Hard-Drawn** and **Soft-Annealed** copper, selecting the correct bending tool for each to avoid "kinking" the pipe, which would cause a pressure drop in the system.

VOG Trait: Work Ready

- **Example:** A student demonstrates "Industry Readiness" by correctly identifying and organizing various fastening and sealing materials, such as **stay-brite solder, silver brazing rods, and flux**. They can match the specific alloy to the temperature requirements of the task (e.g., using high-temperature brazing for high-pressure refrigerant lines).
- **Example:** After a shop session, the student cleans their **flaring and swaging tools**, ensuring the cones are free of debris, which is a standard professional practice to ensure the next leak-free connection.
- **Example:** Students will be able to identify and use mechanical skills to properly connect various pipe and tubing concepts.

VOG Trait: An Effective Communicator

- **Example:** The student creates a "Tool Safety & Use" guide for a peer, clearly labeling the parts of a **tubing bender** and providing step-by-step written instructions on how to achieve a precise 90-degree offset without wasting material.

VOG Trait: A Problem Solver

- **Example:** While practicing a flare joint, the student notices the copper is splitting. Instead of continuing, they stop to analyze the cause—determining if the tubing was over-hardened or if the flaring block was set too high—and then adjusts their technique to create a perfect, leak-proof seal.

Priority Standard 9-6: Effects of heat energy and pressure on the properties of matter.	
Big Idea(s): **1. Heat and pressure drive changes in matter, and understanding these principles helps HVAC technicians manage systems that regulate indoor environments.**	
Essential Question(s): **1. Why does water boil at a different temperature at sea level compared to a higher elevation?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
9-6.A Properties of matter and define. • **Solid** • **Liquid** • **Vapor**	**1. Classify matter according to its different states.**
9-6.B Properties of matter.	**1. Explain how the atmospheric pressure at sea level is higher than that at higher elevations.**
9-6.C Heat and Temperature.	**1. Identify the different scales of temperature measurements.** **2. Explain how heat is energy that is measured in British Thermal Units.** **3. Compare and contrast heat and temperature.**
9-6.D Heat flow rates	**1. Identify heat flow from hot to cold.**
9-6.E Heat transfer types.	**1. Identify radiant, conduction and convection heat transfer methods.**
9-6.F Specific heat value of a substance.	**1. Identify temperature scales.** **2. Identify and demonstrate how the boiling, freezing and absolute zero points are used as reference for these scales.**

9-6.G Change of state of matter based on temperature change.	**1. Identify temperature scales.** **2. Identify and demonstrate how the boiling, freezing and absolute zero points are used as reference for these scales.**
9-6.H Sensible heat effect.	**1. Identify how sensible heat causes temperature changes**
9-6. I Specific heat effect.	**1. Identify how specific heat is different for amounts of sensible heat required to change the temperature of substances.**
9-6.J Latent heat effect.	**1. Identify how latent heat cannot be measured as states of matter changes.** **2. Discuss how a fluid can be at temperature that when heat is added or removed the fluid will change state.**
9-6.K Latent and Sensible heat	**1. Describe how latent and sensible heat effect substances as they change between states.** **2. Compare and Contrast Latent and Sensible heat and explain their differences.**
9-6.L Heat/cool storage.	**1. Identify how heat energy or the ability to remove heat energy can be stored.**
9-6.M Latent heat of fusion	**1. Describe the removal of latent heat causing a substance to change from a liquid to solid.** **2.** Explain the process of Latent Heat of Fusion
9-6.N Latent heat of vaporization	**1. Describe the addition of latent heat causing a substance to change from a liquid to vapor.** **2. Explain the process of Latent heat of vaporization**
Link to Proficiency Scale 9-6	
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CTECS HVAC

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• British Thermal Unit (Btu) • Boiling Point • Cold • Absolute Zero • Thermodynamics • Fist Law of Thermodynamics • Second Law of Thermodynamics • Physical States • Solid • Liquid • Vapor/Gas • Absolute temperature scale • Celsius scale • Cold • Energy • Fahrenheit scale • Force(f) • Gas • Heat • Joule(J) • Kelvin scale • Liquid • Mass • Matter • Power • Rankine scale • Solid • Temperature • Weight • Work	• Latent Heat • Change of State • Conduction • Convection • Radiation • Ton of Refrigeration • Sublimate • Heat insulator • Latent heat • Density • Law of conservation of energy • Newton • Potential energy • Kinetic energy • Horsepower(hp) • Foot-pound(ft-lb) • Specific gravity • Specific heat • Specific volume • Watt (W)	• Sensible Heat • Specific Heat • Subcooled • Superheated Vapor • Statured Condition • Saturation Point • Ambient temperature • Enthalpy • Latent heat of fusion • Latent heat of evaporation • Sensible heat • Ton of refrigeration • Therm

Trade Math Crossover:

1. Temperature Scale Conversions

HVAC technicians must work with both Fahrenheit (used for residential comfort) and Celsius (often used in digital controls and international equipment).

- **The Formulas:** * °C = (°F - 32) div 1.8
    - °F = (°C times 1.8) + 32
- **The Scenario:** A high-limit safety switch on a boiler is set to trip at **95°C**.
- **The Math:** Convert this setting to Fahrenheit. If the boiler's analog gauge reads **205°F**, is the system currently operating safely, or is it about to trip the limit switch?

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2. Sensible Heat Calculation (The Specific Heat of Air)
Sensible heat is heat that causes a change in temperature that can be "sensed" by a thermometer, without changing the state of the matter.

- **The Formula:** Q = M times C times Δ T
    - Q = Heat (BTUs)
    - M= Mass of the substance
    - C = Specific Heat (For water, this is 1.0; for air, it is 0.24)
- **The Scenario:** You need to raise the temperature of **50 lbs. of air** from **60°F** to **75°F** (Δ T = 15).
- **The Math:** Using the specific heat of air (0.24), calculate exactly how many BTUs of heat energy must be added to the room.

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3. Pressure-Temperature (P/T) Relationship
In a closed container, as the temperature of a gas increases, the pressure increases. This is a fundamental concept for charging air conditioning systems.

- **The Law (Gay-Lussac's):** $P_1 / T_1 = P_2 / T_2$ (Note: Temperatures must be in Kelvin or Rankine for exact physics, but HVAC uses P/T charts).
- **The Scenario:** A cylinder of R-410A refrigerant is sitting in a service van. In the morning, at **70°F**, the pressure is **201 PSI**. By 2:00 PM, the van has heated up to **110°F**.
- **The Math:** Using a P/T chart, the student finds that at 110°F, the pressure should be **365 PSI**. Calculate the total **Pressure Increase** in PSI. Why is it dangerous to overfill a refrigerant cylinder on a hot day?

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4. Latent Heat and Change of State
Latent heat is the "hidden" heat required to change a substance from a liquid to a gas (evaporation) or a solid to a liquid (melting) without changing its temperature.

- **The Data:** It takes **970 BTUs** to turn 1 lb. of water at 212°F into 1 lb. of steam at 212°F.
- **The Scenario:** An industrial humidifier evaporates **5 lbs. of water per hour**.
- **The Math:** Calculate the total BTUs of latent heat required per hour to keep the humidifier running.
- **HVAC Connection:** This same principle explains how an A/C evaporator "absorbs" heat from a house by boiling refrigerant at a low temperature.

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5. Volume and Pressure (Boyle's Law)

Boyle's Law states that if the volume of a gas decreases, the pressure increases (provided the temperature stays the same).

- **The Formula:** P_1 times V_1 = P_2 \times V_2
- **The Scenario:** A piston in a reciprocating compressor has a volume of **10 cubic inches** (V_1) at a pressure of **100 PSI** (P_1). The piston moves upward, compressing the gas into a volume of only **2 cubic inches** (V_2).
- **The Math:** Calculate the new pressure (P_2) of the gas. How many times higher is the new pressure compared to the starting pressure?

6. **Ton Calculations**: How many tons of refrigeration effect can be obtained from a window air conditioner rated at 18,000 Btu/hr.?
7. **Calculating refrigeration effect:** Determining that an 18,000 BTU/hr. window unit provides **1.5 tons** of cooling (18,000/ 12,000 = 1.5)

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 9 Thermal dynamic principles
- Chapter 10 Temp/Pressure

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 4,5. Energy and matter, gasses

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 1 Heat/Temperature Pressure
- Unit 2 Matter & energy

OSHA.Gov:
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0006 HVAC Math (complete course)

VOG Portfolio Collection Examples

VOG Trait: An Effective Communicator

- **Example:** The student accurately describes the three methods of heat transfer (conduction, convection, and radiation) to a peer, using real-world HVAC examples like a heat exchanger or a radiator to illustrate each concept.

- A student in the HVAC/R trade will be an effective communicator and be able to explain the three physical states of matter and how superheat and subcooling affect a substance.

VOG Trait: A Critical Thinker

- **Example:** A student uses a Pressure-Temperature (P/T) chart to explain why water boils at a lower temperature at high elevations than at sea level, demonstrating an understanding of how atmospheric pressure dictates the physical state of matter.

Priority Standard 9-7: Sheet Metal Basics	
Big Idea(s): 1. **Developing precision and craftsmanship in sheet metal work equips students to fabricate essential components for air distribution in HVAC systems.**	
Essential Question(s): 1. **What are some HVAC projects a technician would encounter acquire the use of their sheet metal skills?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
9-7.A Sheet metal bending with machines, Sheet metal hand tools	1. **Listing and describing the use of at least 10 sheet metal hand tools.** 2. **Identify by name all the sheet metal working machines shown and describe their basic purpose.** 3. **Construction of assigned projects.**
9-7.B Sheet metal Cutting Tools and sheet metal hand tools from sheet metal blueprint(s)/drawing(s)	1. **Formulate and construct assigned projects.** 2. **Identify by name sheet metal hand tools.**
9-7.C Basic sheet metal duct fittings	1. **Identify different fittings by formulating and classifying duct fitting from blueprint(s)/ drawing(s)**
9-7.D Characteristics of sheet metals.	1. **Explain the type of gauge measuring system used on any of the common sheet metals.** 2. **Read the thickness of sheet metal by using a micrometer.** 3. **Read the thickness of a piece of sheet metal from a gauge table.**

9-7.E Commonly used types of fasteners,	**1. Describe tinners' rivets and explain how they are designated for size.** **2. Describe sheet metal screws and lag bolts.** **3. Describe the following welding process:** **a. Oxyacetylene d. Arc** **b. Mig e. TIG** **c. Spot**
9-7.F Sheet metal cutting patterns	**1. Draw a smooth curve through these points with the use of a flexible rule.** **2. Draw the circumference of the circle to the nearest 1/16 of an inch.** **3. Figure the circumference to the nearest 1/16 of an inch using mathematics.** **4. Use sheet metal snips to cut out any pattern or any kind of inside hole while observing the seven rules for the proper use and care of snips.** **5. Identify the following tools and machines:** **a. Compound shears** **b. Bench level shears** **c. Pipe crimper** **d. Nibbler** **e. Double-cutting shears** **f. Squaring shears**
9-7.G Hole forming in sheet metal	**1. Make a riveted sheet metal seam.** **2. Remove rivets without damaging the sheet metal.**
9-7.H Sketches, and sectional view and allowances • **Grooved seam** • **Standing seam** • **Pittsburgh seam** • **Double seam** • **Dovetail seam**	**1. Use of the bar folder, making all normal adjustments** **2. Use of the bending brake safely, making all the ordinary adjustments for bending sheet metal** **3. Describe sketches how forming molds are used on a bending brake.** **4. Use of sketches, show how the drive-clip and the S-clip are used to loin sections of duct**

9-7. I Sheet Metal Machines: • **Turning machine** • **Burring machine** • **Combination machine** • **Raising**	**1. Turned edge, make a burred edge, make a wired edge, Raise a circular piece of metal**
9-7.J Sheet Metal: ● **Forming** ● **Crimping** ● **Beading**	**1. Explain the difference between the plain forming machine and the slip roll forming machine.** **2. Identify the correct machine for each of the following tasks and explain how it is used for Forming** **3. Identify the correct machine for each of the following tasks and explain how it is used for Crimping** **4. Identify the correct machine for each of the following tasks and explain how it is used for Beading**
9-7.K Metal Joining Techniques	**1. Define the following terms:** 1. **Soft solder** 2. **Hard solder** 3. **Flux** 4. **50-50 solder** 5. **Raw acid** 6. **Cut acid** 7. **Tinning** 8. **Sweating** 9. **Skimming** 10. **Tacking** 11. **Soldering** **2. List at least seven items that will make a poor soldering job** **3. Sweat solder, tack, or skim solders a flat seam of sheet metal.** **4. Tin a soldering copper**
Link to Proficiency Scale 9-7	
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CTECS HVAC

- Tier 2: High-frequency academic words (Used across various subjects/trades).
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Tier 1 (Everyday)	**Tier 2 (Academic)**	**Tier 3 (Technical/Trade)**
• Furnace • Horizontal Furnace • Up Flow Furnace • Multi Position Furnace • Duct board • Sheet Metal • Supply Air • Return Air • CFM • Pattern • Template • Layout • Notching • Hand brake • Ductwork • Blind rivets • Self-piercing screws • Galvanized	• Boot • Bonnet • Drive Cleat • Branch Line • Take off • Trunk Line • Starting Collar • Register • Plenum • Bonnet • Round Duct • Rectangular Duct • Aviation snips • Elevation view • Pictorial drawing • Plan view • Shears • S-slips • Drives	• Vapor Barrier • A-Coil • Mastic • Perimeter System • Diffuser • Insulated Flexible Duct • Insulation • Grilles • Pittsburg seam • Crimping • Hand seamers • Plenum • Sheet metal gauge

Trade Math Crossover:

Focus: Layout geometry and circumference calculations.

- **Duct Pattern Development:** Students must formulate and construct assigned projects by identifying named tools and machines.
    - **Math Example:** To create a round duct fitting, calculate the required flat sheet metal width by figuring the circumference of a 6-inch diameter circle to the nearest 1/16 of an inch.
- **Precision Measurement (Micrometers):** Students learn to read the thickness of different sheet metal gauges.

- **Math Example:** Use a micrometer to measure a sheet of metal and compare the decimal reading to a standard gauge table to identify if the material is 24-gauge or 26-gauge steel.

CFM Calculations:

- How many CFM is required for a one-ton refrigeration system to have proper air flow?
- Calculating the perimeter of a duct to determine the flat sheet size before adding seam allowances (e.g., a 10"x10" duct requires 40" of metal).

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 29 Ductwork

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 29 Air Distribution

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 38 Installation

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Apprenticeship Correlation

A2902 HVAC Sheet metal Theory 2

VOG Portfolio Collection Examples

VOG Trait: A Problem Solver

- **Example:** While fabricating a basic duct fitting, the student identifies an error in their layout pattern. Instead of discarding the material, they use mathematical "circumference to the nearest 1/16th of an inch" calculations to adjust the piece and ensure a proper fit.
- Students will be able to construct a sheet metal fitting by using duct layout and using various sheet metal machinery to produce a product.

VOG Trait: Skilled Socially

- **Example:** Students work in pairs to safely operate a large sheet metal brake, coordinating their movements and using clear verbal cues to ensure the metal is bent accurately without injury.

VOG Trait: Work Ready

- **Example: Precision Duct Component Fabrication:** Description: Using sheet metal hand tools and machines, students must layout and fabricate a specific duct fitting from a blueprint. They are assessed on their ability to follow systematic procedures and maintain a clean workspace.

Priority Standard 9-8: Electrical values and circuits including ohm's law and rules for different electrical circuits.	
Big Idea(s): 1. Electricity is the heartbeat of HVAC systems, and understanding electrical values and relationships empowers technicians to diagnose and build systems safely and accurately.	
Essential Question (s): 1. What happens if the voltage applied to a circuit changes and how does this effect other electrical values?	
Learning Outcomes	
Students will know:	*As evidenced by:*
9-8.A Electrical values with Ohms law: ● Watts ● Ohms ● Volts ● Amps	1. Define watts, ohms, volts, and amps. 2. Calculate the equivalent resistance in a parallel & series circuit 3. Utilize algebra and math skills with Ohm's Law to solve for unknown values
9-8.B Electrical meters to measure circuit values in different types of circuits: ● Ohms, Volts, Amps ● Series, Parallel ● Series – parallel	1. Practice measuring voltage, resistance and current with digital and analog voltmeters and clamp-on ammeter 2. Perform a continuity tester to determine whether an open circuit or dead short exists 3. Construct and analyze a series, parallel, and series-parallel circuit
9-8.D Single- and three-phase voltage.	1. Identify different types of electrical loads, resistive, capacitive and inductive

	2. Perform a capacitance test on run and start capacitors
9-8.E Magnetism in electricity.	**1. Identify single and three-phase circuits.**
9-8.F Magnetic Theory	**1. Describe magnetic theory and applying magnetic principles to electrical theory.** **2. Explain the law of charges.**
9-8.F Conductors and insulators.	**1. Differentiate between conductors and insulators.**

Link to Proficiency Scale 9-8

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Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Atom, Electrons, Nucleus, Protons • Electricity • Potential Difference • EMF(Electromotive Force)(Volts) • Amperage • Resistance • Ohm's Law • Alternating current(ac) • ampere • atom • circuit • conductor • coulomb • Current • Direct current(dc) • Electrical load • Electrical power • electricity • Electromotive force (emf) • Electron	• Continuity • Open Circuit • Short Circuit • Watts • Multimeter • Conductors • Ampacity • Electrical Loads • Ammeter • Busbar • Back-electromotive force(back-emf) • Continuity • Conduit • Disconnects • Grounded • Potential difference • Lock out/Tag out • Line voltage • Stranded • Poles • Switch • Schematic	• Switches, (SPST,SPDT,DPST,DPDT) • Disconnects • Direct Current (DC) • Alternating Current (AC) • Hertz • Polyphase Generation (Three Phase) • L-1, L-2, Neural, Ground • Contacts • conductance • Open circuit • Closed circuit • Parallel circuit • Series circuit • Three phase • Single phase • Voltage drop • Short circuit

• Fuse • Insulator • Ohms • Ohm's law • Voltage • Watt • Watt meter • Wire • Proton	• Ground fault • Multi-meter	

Trade Math Crossover:

Focus: Introductory algebraic relationships in circuits.

- **The Basic Electrical Equation:** Students learn the relationship between Watts, Ohms, Volts, and Amps.
    - **Math Example (Ohm's Law):** If a simple resistive heating element is powered by a 120V circuit and has a resistance of 10 Ohms, calculate the current (Amps) flowing through the circuit (I = V / R).
- **Power Consumption:**
    - **Math Example:** Calculate the total wattage (Power) used by the same 120V circuit drawing 12 Amps (P = V times I).

Sample Calculations:

- A home heating system requires 120 vac of electricity and has a 14/2-gauge Romex wire rated for 15 amps. How many watts are required for this heating system to operate?
- Using E = I times R to calculate the expected resistance in a circuit if the voltage and amperage are known.

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 23 What is Electricity

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 13 Electrical Power

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 12 basic Electricity and Magnetism

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Apprenticeship Correlation

A0782 Electrical Fundamentals

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** A student uses a "Durable AI" simulator to predict what happens to the total amperage in a circuit when more resistance is added. They then act as an "Expert Verifier" by using a multimeter on a physical test bench to confirm if Ohm's Law matches the real-world results.

VOG Trait: Work Ready

- **Example:** Students can wire a basic heating or cooling system using parallel and series wiring

Priority Standard 9-9: Electrical diagrams are used in HVAC	
Big Idea (s): 1. **Electrical diagrams are essential blueprints that guide technicians in understanding, assembling, and troubleshooting HVAC equipment correctly and safely.**	
Essential Question(s): 1. **HVAC technicians must have a thorough knowledge of electrical theory to support different types of equipment. Why do manufacturers have different wiring schematics?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
9-9.A Electrical diagrams ● **Ladder** ● **Pictorial**	1. **Using basic electrical diagrams to identify loads and their controls.** *2.* **Identifying examples of basic electrical symbols used in diagrams.**
9-9.B Electrical measurements ● **Voltage** ● **Amperage** ● **Resistance** ● **Wattage**	1. **Explaining voltage as electrical pressure.** 2. **Explaining ohms as a way to measure resistance to electron flow.** 3. **Explaining amps as electron flow.** 4. **Explaining watts/power a way to measure electrical energy consumed.**
9-9.C Electrical circuits types: ● **Series** ● **Parallel** ● **Series/Parallel**	1. **Calculating electrical values in a series, a parallel, and series-parallel circuit.**
9-9.D Electrical circuits switching	1. **Drawing basic electrical circuits that demonstrate an understanding of switches controlling electrical loads.**
9-9.E Electrical circuits types such as: ● **Voltage**	1. **Measuring voltage with digital and analog voltmeters.**

• **AC current** • **Resistance**	**2. Measuring AC current with a clamp-on ammeter.** **3. Measuring resistance with an ohmmeter.**

Link to Proficiency Scale 9-9

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- Tier 3: Low-frequency, domain-specific technical terms (The “Language of the Trade”).

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Voltage, Amps, Resistance • Schematic • Pictorial Diagram • Ladder Diagram • Ohms Law	• Series • Parallel • Series/Parallel • Continuity • Intensity/Amps • Watts	• VOM (volt-ohm meter) • Open Circuit • Short Circuit • Clamp Meter • Multimeter • Switches

Trade Math Crossover:

1. Identifying Symbols and Circuit Logic: Before performing math, a student must correctly identify the "load" and "control" symbols on a ladder diagram.

- **The Scenario:** A ladder diagram shows a 120V power supply, a closed thermostat switch, and a motor with a resistance of 15 Ohms.
- **The Math:** Using Ohm’s Law (I = V / R), calculate the current (Amps) that will flow through the circuit when the thermostat closes.
- **The Logic:** If the diagram shows two switches in **series** (a thermostat and a high-limit safety), and the high-limit is open, what is the calculated Amperage of the circuit? (Answer: 0 Amps, as the path is broken).

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2. Series vs. Parallel Loads: HVAC diagrams often feature multiple components. Students must use math to understand how voltage and resistance behave differently in these configurations.

- **Parallel Circuit (Standard):** A furnace diagram shows a blower motor and a humidifier wired in parallel.
  - **The Rule:** In a parallel circuit, Voltage remains the same across all branches.
  - **The Math:** If the total voltage is 120V, and Branch A (Motor) draws 8 Amps while Branch B (Humidifier) draws 2 Amps, calculate the **Total Current** ($I_t = I_1 + I_2$) that the circuit breaker must handle.
- **Series Circuit (Safety):** If two 120V heat strips were accidentally wired in series (a common mistake), the voltage would split.
  - **The Math:** Calculate the voltage available to each heater if they have equal resistance (120V / 2 = 60V). How would this affect the heat output?

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3. Interpreting Transformer Ratios: Most HVAC diagrams feature a **Step-Down Transformer** to convert 120V (high voltage) to 24V (low voltage control).

- **The Formula:** $V_p / V_s = N_p / N_s$ (Voltage Primary / Voltage Secondary = Number of turns Primary / Number of turns Secondary).
- **The Math:** If a transformer has 500 turns on the primary side (120V), calculate how many turns must be on the secondary side to produce exactly 24V for the thermostat circuit.
- **The Power Rating (VA):** If a transformer is rated at 40VA (Volt-Amps), calculate the maximum current it can handle on the 24V side before the fuse blows (I = VA / V).

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4. Wire Sizing and Voltage Drop: Technicians use diagrams to determine where to land wires, but they must also use math to ensure the wire is thick enough for the run.

- **The Data:** A diagram calls for a 10-gauge wire for a condensing unit. According to the NEC (National Electrical Code), 10-gauge copper has a resistance of roughly 1.2 Ohms per 1,000 feet.
- **The Scenario:** The unit is 100 feet away from the panel (total wire path is 200 feet). The unit draws 30 Amps.

- **The Math:** Calculate the **Voltage Drop** (V = I times R). If the starting voltage is 240V, and the voltage drop exceeds 3% (7.2V), is the 10-gauge wire sufficient, or must the student "upsize" to 8-gauge?

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5. Reading Component Data from the Diagram: Diagrams often include a "Legend" or "Table" that provides specific electrical values for troubleshooting.

- **The Scenario:** The diagram's legend states the Crankcase Heater should have a resistance of 4,800 Ohms.
- **The Math:** If the technician measures the heater and finds it is only drawing 0.01 Amps on a 240V circuit, use Ohm's Law to calculate the *actual* resistance (R = V / I).
- **The Diagnostic:** Does the calculated resistance match the diagram's legend? If not, is the component failing?

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6. Baseboard Sizing: There are two electrical baseboards installed in a room. One baseboard has a resistance of 291 ohms and the second baseboard has 97 ohms. What is the total resistance of the baseboard for that room?

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599
- Chapter 23 What is Electricity

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545
- Chapter 13 Electrical Power

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5
- Unit 12 basic Electricity and Magnetism

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Apprenticeship Correlation

A0782 Electrical Fundamentals

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** When looking at a ladder diagram for a basic furnace, the student can differentiate between the **power circuit** (high voltage for the blower motor) and the **control circuit** (low voltage for the thermostat). They can explain how a transformer acts as the bridge between these two "worlds" to ensure system safety.
- **Example:** A student identifies the difference between a **pictorial diagram** (showing what the unit looks like) and a **schematic/ladder diagram** (showing how the electricity flows), explaining why the ladder diagram is the superior tool for logical troubleshooting

VOG Trait: A Problem Solver

- **Example:** Given a diagram with a "broken" symbol (e.g., a stuck-open high-limit switch), the student can trace the path of electricity to predict exactly which components will fail to energize. This "mental simulation" allows them to solve the problem on paper before ever picking up a meter.
- **Example:** Students can identify parallel and series circuits within a ladder diagram and trouble shoot equipment malfunction.

VOG Trait: An Effective Communicator

- **Example:** The student can translate a complex electrical schematic into a simple verbal "sequence of operation." For example: *"First, the thermostat closes, then the inducer motor starts, and finally the gas valve opens."* Being able to explain this clearly to a customer or supervisor demonstrates high-level technical communication.

VOG Trait: Work Ready

- **Example:** The student demonstrates the ability to locate the electrical diagram on a piece of equipment (usually inside the service panel) and uses it to verify that the field wiring matches the manufacturer's requirements. They recognize that a missing or unreadable diagram is a major job site hurdle and document it in their service report.

Priority Standard 9-10: Comprehend how codes and their regulations affect the HVAC trade.	
Big Idea(s): 1. **HVAC professionals must follow industry codes and manufacturer guidelines to ensure safety, efficiency, and legal compliance in all installations and repairs.**	
Essential Question(s): 1. **How do the code books work in conjunction with the manufacture's installation instructions?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
9-10.A Codes relating to safety.	1. **Identifying codes as regulations for safe installations and repairs that which also insure proper system operation**
9-10.B Codes resource books.	1. ***Recognizing the difference between BOCA, SBCCI and ICBO, IMC, NFPA.***
9-10.C Codes and standards for the applicable area, locally and state.	1. ***Given examples of enforcement of codes by building inspectors*** 2. **Providing examples of what IRC IMC, NFPA codes as standards used in CT**
9-10.D Relationship between codes and manufacturers' installation instructions.	1. **Identifying how local codes and manufacture instructions will supersede the code due to pertinent standards.**
9-10.E Pertinent standards published and established by AGA, AMCA, ANSI, ARI, ASHRAE, IED, ISO, SMACNA, IMC, NFPA and UL.	1. **Named pertinent standards published by AGA, AMCA, ANSI, ARI, ASHRAE, IED, ISO, SMACNA, IMC, NFPA, and UL.**
9-10.F Code Identification as it relates to the solar trades. (Reference NABCEP 1.6)	1. **Identify and implement appropriate codes and standards concerning installation, operation and maintenance of solar thermal systems and equipment. (Reference NABCEP 1.6)**
Link to Proficiency Scale 9-10	

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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• CODES • IMC • IRC • NFPA 51 • NFPA 54 • Regulations • Manufactures • Standards • Installation • OSHA	• Definitions • General Info • Chapters • Local codes • State codes • National codes • Underwriters Laboratories (UL)	• Annex • BOCA • SBCCI CABO • ICBO • SMACNA • ASHRAE • ANSI

Trade Math Crossover: **(VOG: A Critical Thinker/A Problem Solver)**

1. Identifying Symbols and Circuit Logic: Before performing math, a student must correctly identify the "load" and "control" symbols on a ladder diagram.

- **The Scenario:** A ladder diagram shows a 120V power supply, a closed thermostat switch, and a motor with a resistance of 15 Ohms.
- **The Math:** Using Ohm's Law (I=V/R), calculate the current (Amps) that will flow through the circuit when the thermostat closes.
- **The Logic:** If the diagram shows two switches in **series** (a thermostat and a high-limit safety), and the high-limit is open, what is the calculated Amperage of the circuit? (Answer: 0 Amps, as the path is broken).

2. Series vs. Parallel Loads

HVAC diagrams often feature multiple components. Students must use math to understand how voltage and resistance behave differently in these configurations.

- **Parallel Circuit (Standard):** A furnace diagram shows a blower motor and a humidifier wired in parallel.
    - **The Rule:** In a parallel circuit, Voltage remains the same across all branches.
    - **The Math:** If the total voltage is 120V, and Branch A (Motor) draws 8 Amps while Branch B (Humidifier) draws 2 Amps, calculate the **Total Current** ($I_t=I_1+I_2$) that the circuit breaker must handle.
- **Series Circuit (Safety):** If two 120V heat strips were accidentally wired in series (a common mistake), the voltage would split.
    - **The Math:** Calculate the voltage available to each heater if they have equal resistance (120V/2=60V). How would this affect the heat output?

3. Interpreting Transformer Ratios

Most HVAC diagrams feature a **Step-Down Transformer** to convert 120V (high voltage) to 24V (low voltage control).

- **The Formula:** $V_s/V_p=N_s/N_p$ (Voltage Primary / Voltage Secondary = Number of turns Primary / Number of turns Secondary).
- **The Math:** If a transformer has 500 turns on the primary side (120V), calculate how many turns must be on the secondary side to produce exactly 24V for the thermostat circuit.
- **The Power Rating (VA):** If a transformer is rated at 40VA (Volt-Amps), calculate the maximum current it can handle on the 24V side before the fuse blows (I=VA/V).

4. Wire Sizing and Voltage Drop

Technicians use diagrams to determine where to land wires, but they must also use math to ensure the wire is thick enough for the run.

- **The Data:** A diagram calls for a 10-gauge wire for a condensing unit. According to the NEC (National Electrical Code), 10-gauge copper has a resistance of roughly 1.2 Ohms per 1,000 feet.
- **The Scenario:** The unit is 100 feet away from the panel (total wire path is 200 feet). The unit draws 30 Amps.

- **The Math:** Calculate the **Voltage Drop** (V=I×R). If the starting voltage is 240V, and the voltage drop exceeds 3% (7.2V), is the 10-gauge wire sufficient, or must the student "upsize" to 8-gauge?

5. Reading Component Data from the Diagram

Diagrams often include a "Legend" or "Table" that provides specific electrical values for troubleshooting.

- **The Scenario:** The diagram's legend states the Crankcase Heater should have a resistance of 4,800 Ohms.
- **The Math:** If the technician measures the heater and finds it is only drawing 0.01 Amps on a 240V circuit, use Ohm's Law to calculate the *actual* resistance (R=V/I).
- **The Diagnostic:** Does the calculated resistance match the diagram's legend? If not, is the component failing?

Suggested Resources

International Mechanical Code book
NFPA Books

WWW.ICCSAFE

SMACNA.ORG

OSHA.Gov:
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0730 Related Codes and Standards
A2906 SMACNA
A0729 Relating Codes and Standards

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** The student writes a reflection on how following mechanical codes and EPA regulations directly protects the community's health and environment by preventing carbon monoxide leaks and ozone depletion.
- **Example:** Students will be able to calculate the cubic ft of air needed for an installation of 100,000 btu oil fired appliances installed in a customer's basement.

CTECS HVAC

CTECS

CONNECTICUT TECHNICAL EDUCATION AND CAREER SYSTEM

HVAC

Grade 10

Grade 10 Curriculum

Priority Standard 10-1: Shop and Site Safety	
Big Idea(s): 1. **Safe behavior, responsibility, and professionalism are essential habits that protect lives and build trust in the HVAC workplace.**	
Essential Question(s): 1. **How does the way we behave at school and on a work, site affect safety, and why is it important to follow safety rules and guidelines?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
10-1.A OSHA standards for job site safety.	1. **Wear safety eye protection and hearing protection.** 2. **Explain OSHA and how requiring safety standards and implementation helps everyone.** 3. **Explain proper procedures when using safety equipment (e.g., footwear, hearing protection, hardhat, goggles, and gloves).**

	4. Exhibit proper ladder safety. **5. Demonstrate safe/proper lifting procedures.**
10-1.B Substance abuse effects.	**1. Describe examples of the reasons why technicians cannot work safely while under the influence of any substance that interferes with coordination and decision making and how it negatively can impact safety in the working field.**
10-1.C Positive work habits	**1. Demonstrate good housekeeping practices.** **2. Explain why practicing excellent work habits in school will make using them at work a secondary concern.**
10-1.D Types of safe clothing and safety equipment.	**3. Describe reasons for proper clothing and safety equipment.**
10-1.E The proper procedures when working with hands-on live equipment: • **Electrocution** • **Personal injury**	**1. Identify why the grounding conductor makes an electric tool and equipment safer.** **2. Explain how a small amount of amperage can cause electrical burns and cardiac defibrillation.** **3. Identify how it is safest to work on non-live circuits relating**
10-1.F Ground fault circuit interrupters.	**1. Explain how ground fault interrupter since a small amount of stray amperage tripping to protect from electrocution.**
10-1.G Proper storage and handling of: • **Oxygen** • **Nitrogen** • **Acetylene bottles**	**1. Demonstrate safe use of high-pressure regulators.** **2. Demonstrate how to safely store and handle high-pressure gases and the importance of keeping the cap in place and strapping and storing cylinders in their upright position.**

10-1.H Handle, use and dispose of hardware material.	**1. Describe ways to handle and dispose of hardware, especially sharp materials(s)/item(s).**
10-1.I Environmental safety and review practices.	**1. Identify proper handling of hazardous materials** **2. Explain proper disposal of hazardous materials**
10-1.J Safe driving practices.	**1. Research why the insurance companies of employers will require driving records.**

Link to Proficiency Scale 10-1

Tiered Vocab- HVAC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:

- Tier 1: Common, everyday words (Basic communication).
- Tier 2: High-frequency academic words (Used across various subjects/trades).
- Tier 3: Low-frequency, domain-specific technical terms (The “Language of the Trade”).

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Hazard • PPE • OSHA • Eye Hazard • Head Hazard • Electrical Hard • Fire Hazard • Breathing Hazard • Fall Protection • First Aid	• Fire Extinguishers (Type A, B,C,D) • Temperature Hazards • Pressure Hazards • Refrigerant Hazards • Chemical Hazards • Eye Protection • Electrical Protection • Confined Space • Head Protection • Hearing Protection • Protective Clothing • Respirator	• Hazzard Assessment • OSHA • Lockout/Tag Out • Ladder Safety • Fall Prevention Training • Safety Certifications

Trade Math Crossover:

1. The Physics of Fall Protection: When working on rooftops or high equipment, technicians must use a Personal Fall Arrest System (PFAS). You must calculate the "Total Fall Distance" to ensure you don't hit the ground before the harness catches you.

- **The Components:** * Lanyard Length: 6 feet
  - Deceleration (Shock Absorber) Distance: 3.5 feet
  - Harness Stretch/D-ring Slide: 1 foot
  - Safety Factor (Clearance): 3 feet
- **The Math:** Calculate the **Total Required Clearance** by adding these values together.
- **The Safety Check:** If you are working on a suspended furnace that is 12 feet above a concrete floor, is a standard 6-foot lanyard a safe choice? Why or why not?

2. Ladder Safety: The High-Reach Calculation: 10th graders often work with extension ladders to access rooftop units (RTUs).

- **The Rule:** A ladder must extend exactly 3 feet above the "disembarkation point" (the roof edge) for a safe transition.
- **The Scenario:** A building's roof edge is 21 feet high.
- **The Math:** 1. Calculate the total ladder length needed (21 + 3 feet).

2. Using the **4-to-1 Safety Ratio**, calculate how many feet away from the wall the base of this ladder must be placed (24 div 4).

3. Safe Lifting and Load Limits: Technicians must often move heavy compressors or motors. Overexertion is a leading cause of shop injury.

- **The Scenario:** A new compressor weighs 145 lbs. OSHA suggests a "Recommended Weight Limit" (RWL) for a single person is roughly 51 lbs. under ideal conditions.
- **The Math:** How many technicians are mathematically required to lift this compressor if each person handles exactly their RWL?
- **The Mechanical Advantage:** If you use a hand truck that provides a **3-to-1 mechanical advantage**, how much "effective weight" (effort) will a single technician actually feel when tilting the 145-lb compressor back?

4. Trenching and Excavation Safety: HVAC technicians often dig for geothermal loops or underground refrigerant lines.

- **The Rule:** Any trench 5 feet or deeper must have a protective system (shoring or shielding).
- **The Scenario:** You are digging a trench that slopes downward. It starts at 3 feet deep. Every 10 feet of length, the trench gets 6 inches deeper.
- **The Math:** At what distance (in feet) will the trench reach the 5-foot "Danger Zone" where shoring is legally required?

5. Fire Extinguisher "Pressure-Time" Logic: In the event of a shop fire, a technician has a very limited window to act.

- **The Data:** A standard 10-lb ABC fire extinguisher has a continuous discharge time of approximately 20 seconds.
- **The Scenario:** A small grease fire breaks out. It takes 3 seconds to "Pull, Aim, and Squeeze."
- **The Math:** What percentage of your total fire-fighting capacity is left after your first 5-second burst? If the fire is not out, and you have 12 seconds of discharge left, what is your remaining "margin of error" in seconds?

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 3. Safety

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Section 1, Chapter 2. Safety

Basic Principles for Construction, 4^{th} Edition (Residential Construction Academy) 4^{th} Edition

ISBN-13: 978-1-3050-8862-7

- Chapter 3. Job Safety
- Chapter 5. Safety with Scaffolds

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

OSHA 30: A0099

VOG Portfolio Collection Examples

VOG Trait: Work Ready

- **Example:** A student completes their **OSHA-10 or OSHA-30 certification**, demonstrating the formal safety credentials required for employment in the Connecticut construction industry.
- **Example:** The student consistently demonstrates "professional conduct" by showing up to the shop or worksite in the required CTECS uniform, including properly fitted work boots and a hard hat, and removing all jewelry before beginning technical tasks.
- **Example:** Students working on equipment will use a procedure called "Lockout/Tagout" from training they received from their OSHA training.

VOG Trait: An Effective Communicator

- **Example:** During a "Toolbox Talk," a student clearly explains the "Lock-Out/Tag-Out" (LOTO) procedure to a junior peer, using technical terminology to describe why a circuit must be de-energized and physically locked before service begins.
- **Example:** The student can articulate the specific role of OSHA in the workplace, providing examples of how government regulations protect individual workers from site hazards.

VOG Trait: A Problem Solver

- **Example:** When identifying a "near-miss" hazard on a job site—such as a slippery floor or an unsecured ladder—the student does not just walk past it; they take the initiative to mark the area or fix the issue, demonstrating a proactive approach to hazard mitigation.

VOG Trait: A Critical Thinker

- **Example:** A student evaluates a complex work scenario and determines which specific **Personal Protective Equipment (PPE)** is needed beyond the basics (e.g., selecting ear protection for high-decibel environments or specific gloves for handling sheet metal).

Priority Standard(s): 10-2 Application of trade drawings	
Big Idea(s): 1. **Blueprints are visual tools that translate design into action, helping HVAC technicians plan and build accurate, functional systems.**	
Essential Question(s): 1. **How do you describe what fittings are needed to install duct work? When building sheet metal fittings how would you determine size and shape?** 2. **How can you determine whether a site is a suitable location for solar installations or where on a site to install solar collectors?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
10-2.A HVAC symbols and scaling blueprints.	1. **Identify HVAC symbols and components on a blueprint.**
10-2.B Sheet metal fitting from a given print.	1. **Demonstrate the ability to transpose from a drawing a sheet metal fitting.**
10-2.C Solar Thermal Site Assessment. (Reference NABCEP 4.1-4.9)	1. **Conduct a Solar Thermal Site Assessment. (Reference NABCEP 4.1-4.9)**

	2. Determine the required installation area, orientation, and tilt for proposed collector installation. 3. Establish whether there is suitable installation area with unobstructed solar access for installing collector 4. Determine the extent of current and future shading for any proposed collector location using typical sun path calculators or similar methods 5. Assure structural integrity and suitability of collector site. Determine soil conditions and integrity for footing design and pipe path. (Local codes or site conditions might then require involving an engineer). 6. Determine suitable location for installing all subsystem components (This includes piping, water heater, valves, and ancillary equipment required for complete system installation.) 7. Practice all personnel safety requirements 8. Identify any other constraints and options for the installation related to local and state code requirements 9. Verify that a system to be installed is appropriate for the building and climate 10. Verify with the homeowner the proposed location of the collector and other major components

Link to Proficiency Scale 10-2

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- Tier 1: Common, everyday words (Basic communication).

- Tier 2: High-frequency academic words (Used across various subjects/trades).
- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Furnace • Horizontal Furnace • Up Flow Furnace • Multi Position Furnace • Duct board • Sheet Metal • Supply Air • Return Air	• Boot • Bonnet • Drive Cleat • Branch Line • Take off • Trunk Line • Starting Collar • Register • Plenum • Bonnet • Round Duct • Rectangular Duct	• Vapor Barrier • A-Coil • Mastic • Perimeter System • Diffuser • Insulated Flexible Duct • Insulation • Grilles • CFM

Trade Math Crossover:

1. Architectural Scaling (The Ratio Challenge)

HVAC blueprints are rarely drawn at full size. Students must use a ruler and a scale ratio to determine the actual length of ductwork needed.

- **The Data:** A mechanical plan is drawn at a scale of **1/4" = 1'-0"**.
- **The Scenario:** On the drawing, a straight run of rectangular supply duct measures **6.5 inches** long.
- **The Math:** 1. Calculate how many "quarter inches" are in 6.5 inches (6.5 div 0.25 = 26).

2. Since each 1/4" represents 1 foot, calculate the actual length of the duct in the building (26 feet).

- **The Ordering Logic:** If the shop fabricates duct in 5-foot sections, how many full sections must be loaded onto the truck for this specific run?

2. Obstruction Offsets (The Pythagorean Path)

Trade drawings often show a duct "offsetting" to avoid a plumbing pipe or a steel beam. This creates a right triangle.

- **The Scenario:** A blueprint shows a 12-inch duct that must "jump" 9 inches horizontally to clear an obstacle while traveling 12 inches forward.
- **The Math:** Use the Pythagorean Theorem ($a^2 + b^2 = c^2$) to find the length of the slanted transition piece.
  - 9^2 (81) + 12^2 (144) = 225.
  - Sqrt 225 = 15 inches.
- **The Application:** If the student cuts the metal at 12 inches (the straight distance) instead of 15 inches (the travel distance), explain mathematically why the duct will not reach the next connection.

3. Grille and Register Sizing (Area vs. Velocity)

A drawing's "Reflected Ceiling Plan" shows the location and size of air registers. A technician must ensure the specified grille has enough "Free Area."

- **The Data:** The drawing calls for a **12" x 12"** supply register. However, the metal louvers (the fins) take up 25% of that space.
- **The Math:** 1. Calculate the total gross area (12 \times 12 = 144 sq in).

2. Calculate the "Net Free Area" after subtracting the 25% obstruction (144 \times 0.75 = 108 sq in).

- **Trade Application:** If the unit is pushing 400 CFM of air through that register, calculate the air velocity in feet per minute (FPM). (Formula: Velocity = CFM times 144\ Area).

4. Material Take-Off (Surface Area and Waste)

Standard 10-2 requires students to create a "Take-Off" (a list of materials) from a drawing.

- **The Scenario:** A blueprint shows a rectangular trunk line that is 20" wide, 10" high, and 40 feet long.
- **The Math:** 1. Calculate the perimeter of the duct (20 + 20 + 10 + 10 = 60 inches or 5 feet).

2. Calculate the total surface area in square feet (5 feet perimeter times 40 feet length} = 200 sq ft).

- **The Costing Logic:** If a flat sheet of galvanized steel is 4' x 10' (40 sq ft), how many sheets are mathematically required to build this duct, assuming a 15% waste factor for seams and cuts?

5. Elevation and Hanger Spacing

Blueprints provide "Finished Floor Elevation" (FFE). HVAC equipment must be hung at specific heights to allow for ceiling clearance.

- **The Data:** The FFE is 0'-0". The drawing states the "Bottom of Duct" (BOD) must be at **9'-4"**. The duct itself is **18 inches** tall.
- **The Math:** 1. Convert the BOD to total inches (9 \times 12 + 4 = 112 inches).

2. Calculate the height of the "Top of Duct" (112 + 18 = 130 inches).

- **The Problem:** If the structural steel beams are at 11'-0" (132 inches), calculate the "Clearance Gap" between the top of your duct and the steel. Is there enough room (2 inches) to fit a standard hanger strap?

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 29 Ductwork

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Section 1, Chapter 2.

Basic Principles for Construction, 4th Edition (Residential Construction Academy) 4thEdition

ISBN-13: 978-1111307189

- Section 5 Chapter 18,19,20,21,22,23,24

Print Reading For Construction 6th Edition

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 37 Air Distribution & Balance

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0031 BPR

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** When given a mechanical floor plan, the student identifies a potential "clash" where a return air duct is scheduled to pass through a structural beam. They propose a reroute that maintains the required CFM (Cubic Feet per Minute) while respecting the building's structural integrity.
- **Project: Solar Thermal Site Assessment:** Description: Students analyze a building site to determine the best location for solar collectors, accounting for shading and structural integrity. They must use sun path calculators to make evidence-based decisions.

VOG Trait: An Effective Communicator

- **Example:** The student "walks" an instructor through a blueprint, using proper technical terms like "plenum," "register," and "return" to describe the intended airflow path for a residential split system.

Priority Standard 10-3: Fasteners	
Big Idea(s): 1. **Choosing the correct fastener and tool ensures a secure, lasting installation and demonstrates a technician's skill and attention to detail.**	
Essential Question(s): 1. **When building something how would you decide what to use as fasteners?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
10-3.A Basic hand tools when using fasteners ● **Slotted Screwdrivers** ● **Philips Screwdrivers** ● **Combination wrenches** ● **Socket wrenches** ● **Hex drivers** ● **Torx Drives**	1. **Select the proper tool for the proper application of fasteners.** 2. **Show proper safety techniques and procedures in using hand tools with the fastener selected.**
10-3.B Power tools and their accessories ● **Drill drivers** ● **Hammer drills**	1. **Demonstrate the proper safety techniques and in the use of power tools with a fastener selected.**

• **Drill bit sizing**	2. **Use eye protection and hearing protection during tool use** 3. **Select correct drill for fasteners**
10-3.C Fasteners and proper job application. • **Self-tapping screws** • **Lag bolts** • **Machine bolts** • **Set screws** • **Treaded rod** • **Wood Screws** • **Sheetrock screws** • **Shielded anchors** • **Toggle bolts** • **Concrete anchors** • **Staples** • **Cotter pins** • **Perforated straps** • **Pipe hook** • **Pipe Strap** • **Nylon straps** • **Electrical connectors** • **Electrical terminals**	1. **Identify fasteners** 2. **Apply the use of the proper fastener for the job.**
Link to Proficiency Scale 10-3	
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- Tier 3: Low-frequency, domain-specific technical terms (The “Language of the Trade”).

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• American National Acme Thread • American National • Standard Thread • Bolt • Bolt extractor • Cap screw • International Thread • Machine screw • Major diameter • Nut • Threads per inch • Washer	• Blind rivet • Mandrel • Masonry anchor • Minor diameter • Molly • Root screw • Screw thread • setscrew • Shank • Sheet metal screw • Speed chuck • Threaded rod • Toggle bolt	• Brown and Sharpe Worm thread • Crest • Die • Flexible duct straps • Flutes Thread angle • Self-piercing screw • Self-tapping screw • Tap • Wire ties

Trade Math Crossover:

1. Shear Strength and Equipment Weight: When hanging a horizontal furnace from a ceiling using threaded rods and nuts, the fasteners are under "tension." When mounting a bracket to a wall, the bolts are under "shear" (gravity pulling across the bolt).

- **The Data:** A 1/4-inch Grade 2 steel bolt has a safe shear strength of approximately **600 lbs**.
- **The Scenario:** You are mounting a commercial exhaust fan that weighs **1,800 lbs.** using four of these bolts.
- **The Math:** 1. Calculate the total load each bolt must carry (1,800 div 4 = 450 lbs.).

2. Compare the load (450 lbs.) to the safety rating (600 lbs.).

- **The Safety Factor:** Calculate the "Safety Factor" by dividing the strength by the load ($600 \div 450$). Is this installation over-engineered or at risk of failure if the fan vibrates?

2. Drill Bit and Tap Selection (Decimal Conversion): To create internal threads in a metal plate for a bolt, a technician must drill a hole slightly smaller than the bolt. This is called a "Tap Drill."

- **The Scenario:** You need to tap a hole for a **5/16-inch** bolt. The standard tap drill size is **F (0.257 inches)**.
- **The Math:** 1. Convert the 5/16-inch bolt size to a decimal (5 div 16 = 0.3125").

2. Calculate the difference between the bolt diameter and the drill bit diameter (0.3125 - 0.257).

- **Trade Application:** This difference represents the depth of the threads. If the hole is too large, the threads will be too shallow and will "strip" under pressure.

3. Torque and Clamping Force: In high-pressure systems, bolts on a compressor head must be tightened to a specific "Torque" to ensure a leak-proof seal.

- **The Formula:** Torque = Force \times Distance.
- **The Scenario:** A manufacturer requires a bolt to be torqued to **25 foot-pounds**. You are using a wrench that is **9 inches long**.
- **The Math:** 1. Convert the wrench length to feet (9 div 12 = 0.75 ft).

2. Calculate the amount of force (in pounds) you must pull on the end of that wrench to reach exactly 25 foot-pounds (25 div 0.75).

4. Sheet Metal Screw Count and Static Pressure: In ductwork, screws aren't just for holding metal together; they prevent the duct from "ballooning" under high air pressure.

- **The Rule:** High-pressure ducts require a screw every **6 inches** along the seam.
- **The Scenario:** You are installing a 20-foot run of rectangular ductwork that has 4 seams (corners) running the full length.
- **The Math:** 1. Calculate the total linear footage of seams (20 feet times 4 seams = 80 feet).

2. Since there are 12 inches in a foot, calculate how many total screws are needed if they are spaced 6 inches apart.

5. Anchor Spacing and Concrete Stress: When using "Wedge Anchors" to bolt a heavy condenser to a concrete pad, the anchors cannot be too close together, or they will crack the concrete.

- **The Rule:** Anchors must be spaced at least **10 times** their diameter apart.
- **The Scenario:** You are using **1/2-inch** diameter concrete anchors.

- **The Math:** 1. Calculate the minimum spacing required between two anchors in inches (0.5 \times 10).

2. If the mounting holes on the equipment are only 4 inches apart, can you safely use these 1/2-inch anchors, or must you use a different mounting method to comply with safety math?

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 3. Fasteners

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 8 Reference 7.4 standards and supplies

Basic Principles for Construction, 4th Edition (Residential Construction Academy) 4th Edition

ISBN-13: 978-1111307189

- Chapter 16 Fasteners

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 6 Fasteners

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A2902 HVAC Sheet Metal Theory 2

VOG Portfolio Collection Examples

VOG Trait: Work Ready

- **Example:** Students will be able to use the depth drill gauge when hammer drilling into a concrete installation.
- **Example:** The student demonstrates “Technical Literacy” by correctly identifying fasteners by their trade names and sizes (e.g., “1/4-20 hex bolt”) and matching them with the correct driver or drill bit size, reducing “cam-out” and material damage.

- **Example:** After a shop project, the student organizes their fastener bin, separating galvanized screws from stainless steel to prevent **galvanic corrosion**—a professional habit that ensures the longevity of the installation.

VOG Trait: A Problem Solver

- **Example:** A student encounters a situation where a fastener has stripped out of a metal frame. Instead of leaving it loose, they demonstrate problem-solving by selecting a larger gauge screw or a **pop rivet** to create a permanent, vibration-resistant connection.

VOG Trait: An Effective Communicator

- **Example:** The student creates a "Fastener Application Chart" for the shop, clearly illustrating which screw or bolt should be used for specific HVAC materials (e.g., hanging threaded rod vs. securing a thermostat base).

VOG Trait: A Critical Thinker

- **Example:** A student evaluates a mounting surface and the weight of an evaporator coil to decide between using **toggle bolts** for hollow drywall or **wedge anchors** for solid masonry. They justify their choice based on the "shear" and "tension" loads the fastener must withstand.
- **Example:** When joining two sections of sheet metal duct, the student chooses **self-drilling screws (zip screws)** of the correct length to ensure a tight seal without protruding so far into the duct that they catch debris or cause excessive turbulence.

Priority Standard 10-4: Advanced Sheet Metal	
Big Idea(s): 1. **Advanced sheet metal skills allow HVAC professionals to build complex ductwork systems that control airflow efficiently and meet customer needs.**	
Essential Question(s): 1. **Why do you need a clean and organized work area before starting the layout and fabrication procedures?**	
Leaning Outcomes	
Students will know:	*As evidenced by:*
10-4. A. Six types of patterns and drawings and the information contained in each. • **Straight Duct** • **Reducer fitting** • **90 Degree radius Elbow** • **Offset fitting** • **Plenum** • **Starting tap fitting**	1. **Identify application of patterns to metal** 2. **Describe how to take measurements for pattern development** 3. **Describe the various hand tools and machines to cut metal and pipe.**
10-4.B. Basic Duct Construction.	1. **Evaluate fitting construction including elbows, vane requirements & supports, offsets & transitions, and branch connections and rate**

	the construction with a 1-10 scale with 10 the best. **2. Assemble round and oval duct and meet proper construction standards, pressure gauges for round duct and tees and laterals.**
10-4.C Flexible duct including grill and register connections, canvas connectors, and flexible duct supports.	**1. Prepare and install a flexible duct run starting with the tap and ending at the register.** **2. Calculate what the CFM will be for the above flexible duct run. Performance test what is the actual CFM performance** **3. Assemble a canvas connector and explain the reason for its use.**
10-4. D Sheet metal types and installation standards: • **NFPA 31 Standard for the Installation of Oil Burning Equipment** • **NFPA 54 National Fuel Gas Code** • **NFPA 85 Boiler and Combustion Systems Hazards Code** • **NFPA 90A Standard for the Installation of Air Conditioning and Ventilation Systems** • **NFPA 90B Standard for the Installation of Warm Air heating and Air Conditioning Systems** • **NFPA 96 Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations** • **SMACNA**	**1. Explain where the different standards will be applied.** **2. Formulate what standards will override mechanical codes** **3. Create a blueprint, showing the areas where NFPA standards will be applied. Then calculate the total of overriding standards with mechanical codes and manufacture installation manuals.**
Link to Proficiency Scale 10-4	
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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Damper • Diffuser • Drive • Duct • Duct board • Elbow • Flexible pipe • Grille • Hanger stock • Offset • Plenum • Register • Round pipe • Sheet Metal • Starting tap/collar • S-Slip • Transition	• Axial flow fan • Butterfly damper • Gable fan • Induced draft • Multiple-blade damper • Primary air • Radial flow fan • Return air Duct • Split damper • Supply air duct • Unvented attic • Vented attic • Whole House fan	• Air curtain • Airflow friction chart • Aspect ratio • Effective length • Friction loss • Friction rate • Manual D • Static Pressure • Pressure Losses • Total Pressure drop

Trade Math Crossover:

1. Advanced Sheet Metal: The Geometry of Airflow (Standard 10-4)

10th graders move beyond simple boxes to complex fittings like offsets and radius elbows.

- **The Math (Square to Round):** A student must fabricate a transition that connects a square plenum (16" x 16") to a round trunk line (12" diameter).
- **The Calculation:** To ensure the airflow remains constant, the "Cross-Sectional Area" must be maintained.
    - **Step A:** Calculate the area of the square plenum (16 times 16 = 256 sq in).
    - **Step B:** Calculate the area of the 12-inch round duct ($A = \pi$ times r^2).

- **The Diagnostic:** Does the round duct have enough area to handle the air from the square plenum, or will it cause "Static Pressure" back-up?

2. When sizing a return air duct, 80% of air needs to be returned back to the 24,000 btu air handler. How much return air CFM is required for proper operation?

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 29 Ductwork

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 29 Air Distribution

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-

- Unit 37 Air Distribution & Balance Sheet Metal 2nd edition

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A2905 HVAC Layout 2

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** When tasked with fabricating a "Square-to-Round" transition for a range hood, the student uses **Triangulation Layout** methods to determine the exact dimensions. They explain how an incorrect layout would not only waste material but also cause turbulent airflow and increased static pressure in the system.
- **Example:** The student evaluates the "Gauge" of metal required for a high-velocity duct system versus a residential return, justifying why a thicker metal (lower gauge number) is necessary to prevent "oil-canning" (popping noises) when the blower turns on.

VOG Trait: A Problem Solver

- **Example:** A student identifies that a standard 90-degree elbow will not fit in a tight ceiling plenum. They use trade math to design and fabricate a **Short-Radius Elbow with turning vanes** to move the air efficiently through the restricted space without losing significant CFM (Cubic Feet per Minute).
- **Example:** Students can take a static pressure test on a central air conditioner air handler using the manufacturing data information tag for proper static pressure and equipment operation.

VOG Trait: Work Ready

- **Example:** The student demonstrates mastery of advanced shop machinery, such as the **Pittsburgh Machine** or the **Box and Pan Brake**, ensuring that all seams are “knocked down” tightly and professional-grade sealant is applied to meet ***SMACNA*** (Sheet Metal and Air Conditioning Contractors’ National Association) standards.
- **Example:** Before beginning a large fabrication project, the student creates a “Cut List” and uses a nesting strategy to minimize scrap metal, demonstrating the material-cost awareness expected by an HVAC contractor.

VOG Trait: An Effective Communicator

- **Example:** The student creates a set of “Step-by-Step” fabrication instructions for a **Pittsburgh Seam**, using technical terms like “pocket,” “flange,” and “offset.” They then use these instructions to peer-tutor a classmate, ensuring both students achieve a high-quality result.

Priority Standard 10-5: Ohms law	
Big Idea(s): 1. **Understanding Ohm's Law enables technicians to analyze electrical circuits and ensure safe and efficient system performance.**	
Essential Question(s): 1. **What happens if the voltage applied to a circuit changes?** 2. **How do magnetic theories apply to electricity?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
10-5.A Electrical values with ohms law and formulate: ● **Watts** ● **Ohms** ● **Volts** ● **Amps**	1. **Define watts, ohms, volts, and amps.** 2. **Calculate the equivalent resistance in a parallel & series circuit** 3. **Utilize algebra and math skills with Ohm's Law to solve for unknown values**
10-5.B The use and operation of an electrical meter(s) ● **Ohms**	1. **Demonstrate measuring voltage, resistance current with digital and analog voltmeters and clamp-on ammeter**

• Volts • Amps • Series • Parallel • Series – parallel	2. Demonstrate using a multi meter to test continuity to determine whether an open circuit or dead short exists 3. Construct and analyze a series, parallel, and series-parallel circuit 4. Measure and analyze circuit values in different types of circuits.
10-5.C Electrical loads and analyze such loads: • Resistive • Capacitive • Inductive	1. Identify different types of electrical loads, resistive, capacitive and inductive 2. Demonstrate using capacitance meter to measure capacitance of run and start capacitors
10-5.D Single and three-phase voltage	1. Identify and compare single and three-phase circuits.
10-5.E Applications of magnetism in electricity circuitry.	1. Defining magnetic theory and applying magnetic principles to electrical theory. 2. Defining the law of charges
10-5.F Conductors and insulators.	1. Explain the difference between conductors and insulators
10-5.G Basic generator principle.	1. Explain how magnetic fields induce current flow when a changing magnetic field is applied to a conductor.
10-5.H Electrical distribution within an electrical distribution service panel.	1. Explain electrical distribution from breaker panel to electrical components such as switches and receptacles and other electrical loads.
10-5. I Electrical power sources by identifying and comparison of: • Single-phase • Three-phase	Identify single and three-phase circuit by: 1. Number of conductors 2. Measuring voltages between legs 3. Measuring voltages to ground
Link to Proficiency Scale 10-5	

CTECS HVAC

Tiered Vocab- HVAC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:

- Tier 1: Common, everyday words (Basic communication).
- Tier 2: High-frequency academic words (Used across various subjects/trades).
- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Alternating current(ac) • ampere • atom • brushes • conductor • coulomb • current • electricity • Direct current(dc) • Electricity • Electromotive force(emf) • Electron • Ohm's law • Switch	• AWG • Closed • Circuit • Circuit breaker • Dielectric • Electrical circuit • Electrical load • Fuse • Grounding • Open circuit • Closed circuit • Ground fault interrupter • Load • Resistance • Short circuit • Single phase • Three-phase • Watt's law	• Bonding • Brushes • Capacitance • Capacitor • Electromagnet • Electromagnetism • Farad(F) • Induced magnetism • Induction • Volt-amps • Voltage drop

Trade Math Crossover:

Electrical Load Calculations

- A service technician is called out for a no cooling service call. When checking the power supply at the outdoor disconnect, the technician checks the L-1 terminal to ground and the electrical meter reads 120 vac, then checks the L-2 terminal to ground and 120 vac. What is the circuit's total voltage?
- Solving for unknown electrical values (Watts, Ohms, Volts, Amps) to ensure circuit safety.

<u>Suggested Resources</u>

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 23 What is Electricity

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 13 electrical Power

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 18 Application of motors
- Unit 19 Motor Controls

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0782 Electric Fundamentals

VOG Portfolio Collection Examples

VOG Trait: A Problem Solver

- **Example:** Using Ohm's Law, a student predicts the expected amperage of an AC motor. When their actual multimeter reading is significantly higher, they systematically troubleshoot the circuit to identify a mechanical bind in the motor bearings or a failing capacitor.
- **Example:** Students will be able to check for electrical power at a disconnect using their prior knowledge and use of an electrical meter.

Priority Standard 10-6: Basic electricity, electrical circuits and AC electric motors	
Big Idea(s): 1. **A solid grasp of electrical systems and motor function empowers HVAC technicians to design, install, and troubleshoot modern equipment.**	
Essential Question(s): **1.How do electrical circuits work, and what role do AC electric motors play in powering everyday devices?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
10-6.A Applications of magnetism in electricity in relation to electrical theory.	**1.Define magnetic theory** **2. Exhibit the use, the appropriate meter to check basic electrical components.**
10-6.B Low voltage wiring and controls required for heating and cooling equipment operation.	1. **Exhibit the wiring of a complete low voltage heating and air conditioning control circuit to accommodate a heating furnace with a split cooling system.** 2. **Show how to program a programmable thermostat for heating/cooling including set-up and setback modes.** 3. **Detect and comparing single- and three-phase voltage and current**

10-6.C Different electric motor types: ● Shaded pole ● Split-phase motor (RSIR) ● Multi-speed motor ● Permanent split capacitor (PSC) ● Capacitor start induction run motor ● Capacitor start capacitor run motor ● Electronically controlled motor ● Variable-speed motor	**1. Define the significance of power factor.** **2. Explain starting components associated with single-phase and three-phase motor.** **3. Explain the operation and application of motors and supporting what problems could happen** **4. Explain electric motor theory (i.e., magnetism, electromotive force, etc.).** **5. Explain operation and application of different motors.**
10-6.D Types of electrical loads identification: ● Capacitive ● Inductive ● Resistive	**1. Identify types of electrical loads** **2. Identify the relationships of voltage and amperage in different loads.**
10-6.E Starting components associated with single-phase and three-phase motors and examine: ● centrifugal switch ● current coil relay ● potential relay ● PTC relay	**1. Identify single phase starting components and examine and identify contactors and motor starters**
10-6.F Interpret detailed instructions for wiring circuits.	**2. Identify electrical switch and load symbols used in diagrams.** **3. Draw basic electrical circuits that demonstrate an understanding of switches controlling loads**
10-6.G Basic principles of solid-state switching devices.	**1. Explain how solid-state devices control flow of electrons without mechanical switches that failed due to friction sparks.**

	2. Identify principles of solid-state switching devices.
10-6.H How electricity is produced and distributed, including basic generator principle.	**1. Explain how magnetically produced electricity is transformed and distributed from plants to users through the electrical grid.** **2. Explain how a wire passed through a magnetic field will have a voltage created in it.**
10-6.I The operation and application of motors.	**1. Identify different motor types and uses, small axial fans, squirrel blowers, compressors etc.** **2. Explain proper horsepower of replacement motors.**

[Link to Proficiency Scale 10-6](#)

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- Tier 3: Low-frequency, domain-specific technical terms (The “Language of the Trade”).

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Ac motor • Built-up terminal • Centrifugal switch • Common terminal • Continuous duty • End bell • Nameplate • Rotor • Squirrel cage rotor • Stator	• Full-load amperage (FLA) • Locked rotor amperage (LRA) • Rated full-load (RLA) • Run Capacitor • Run windings • Slip • Start capacitor • Start winding • Synchronous speed	• Capacitor-start, capacitor- • Run (CSCR) motor • Capacitor-start, induction-run (CSIR)motor • Dual-voltage motor • Electronically commutated motor (ECM) • Induction motor

• Terminal box • Torque		• Intermittent duty motor • Permanent • Split capacitor (PSC) motor • Shaded-pole motor • Single-phase motor • Split-phase motor • Three-phase motor • Variable frequency • Drive (VFD)

Trade Math Crossover:

Electrical Load Calculations (Standard 10-5)

Students use Ohm's Law to calculate total system requirements for multi-component units.

- The Scenario: A rooftop unit contains a compressor (drawing 15 Amps), a condenser fan (drawing 2.2 Amps), and a blower motor (drawing 4.5 Amps).
- The Math: Calculate the Total Circuit Amperage (15 + 2.2 + 4.5 = 21.7 Amps).
- The Code Check: According to the "125% Rule" for the largest motor, calculate the minimum wire size needed to prevent a fire.

Resistance Calculations:

Three leads of a compressor are connected. What is the total resistance between (Start) 8 ohms and (Run) 2 Ohms when (Common) is disconnected?

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 25 Induction Motors
- Chapter 26 Control Devices

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 14 Basic Electronics
- Chapter 15 Electric Motors

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 25 Special Refrigeration System components

OSHA.Gov: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593
Apprenticeship Correlation A0782 Electric Fundamentals A0784 Heating Fundamentals A0791 Oil Burner Controls
VOG Portfolio Collection Examples **VOG Trait: Work Ready** • **Example:** A student demonstrates "Expert Verification" by using a "Durable AI" simulator to predict circuit behavior, then physically verifies the results on a live test bench using a calibrated multimeter, documenting the findings in their professional shop log. **VOG Trait: A Problem Solver** • A student will be able to test an electrical capacitors MFD to determine if the component has failed.

Priority Standard 10-7: Describe the use or function of typical electrical components found in HVAC systems	
Big Idea(s): 1. **Recognizing and understanding HVAC electrical components is essential for accurate system wiring and successful system operation.**	
Essential Question(s): 1. **Why are electrical components not required for operation often used in HVAC systems?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
10-7.A The operation and role that basic electrical components play in different applications in the HVAC industry listed below: ● **Capacitors** ● **Contactor** ● **Fan/Limit Controls** ● **Overloads** ● **Relays** ● **Thermostats**	1. **Explain the functions of Capacitors, Contactor, Fan/Limit Controls, Overloads, Relays, Thermostats both low and line voltage**
10-7.B Electrical components troubleshooting.	1. **Demonstrate the sequence of troubleshooting techniques needed for problem solving with electrical components.**

	2. **Demonstrate proper techniques in changing out failed electrical components.**
10-7.C The operation and role of special electrical components: • **Starters** • **Defrost Timers** • **Oil pressure safety** • **Pressure Controls** • **Solenoids** • **Solid state time delays**	1. **Explain the functions of Starters, Defrost Timers, Oil pressure safety, Pressure Controls, Solenoids, Solid state time delays, both low and line voltage (Critical Thinker)**
10-7.D Installing Electrical Control Systems as it pertains to Solar Thermal Systems (Reference NABCEP 9.1, 9.2, 9.4-9.8)	**(Reference NABCEP 9.1, 9.2, 9.4-9.8)** 1. **Determining the location of the controller** 2. **Explain a differential controller and sensors** 3. **Install a timer controller** 4. **Install control wiring** 5. **Select ultraviolet radiation protective method for external wiring** 6. **Explain protecting external wiring from ultraviolet degradation** 7. **Explain test operation of controller**

Link to Proficiency Scale 10-7

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Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)

• Bimetal coil • Bimetal device • Bimetal disc • Bimetal strip • Contactor • Control system • Current relay • Current limiting • Ladder diagram • Motor starter • Pictorial diagram • Potential relay • Relay • Set point • Sensing bulb • Thermostat	• Cut-in Cut-out differential • Differential adjustment • High-pressure Motor control • Lockout • Low-pressure motor control • Low-pressure safety control • Multipurpose fuse • Pressure Motor Control range • Range adjustment • Remote temperature- sensing element • Time-delay fuse • Transformer	• Actuator • Below-atmospheric-pressure element • Direct Digital Control (DDC) • Primary control • Positive Temperature coefficient (PTC) • Solid-state Relay (SSR) • Temperature Motor control • Zone control panel

Trade Math Crossover:

1. Capacitors: The Phase Shift Math

A capacitor stores an electrical charge to help a motor start or run more efficiently. Its "strength" is measured in Microfarads (µF).

- **The Rule:** Most motor capacitors have a tolerance of **±6%**.
- **The Scenario:** A permanent split capacitor (PSC) motor has a nameplate requirement for a **35 µF** capacitor. A technician tests the capacitor with a multimeter and gets a reading of **31.5 µF**.
- **The Math:** 1. Calculate the lower limit of the tolerance (35 times 0.94).

  2. Compare the reading (31.5) to the limit (32.9).

- **The Diagnostic:** Is the capacitor mathematically "in spec," or must it be replaced to prevent the motor from overheating?

2. Contactors and Relays: Vault-Amp (VA) Ratings

A contactor uses a low-voltage coil (24V) to close high-voltage "points" (240V). The coil has a specific power draw measured in Volt-Amps (VA).

- **The Scenario:** A technician is adding a second contactor to a circuit. The transformer is rated at **40 VA**. Contactor A draws **12 VA** and Contactor B draws **15 VA**. The thermostat and other controls draw an additional **8 VA**.
- **The Math:** Calculate the **Total VA Load** (12 + 15 + 8).
- **The Safety Check:** Does the total load exceed the 40 VA rating of the transformer? If the technician adds a third accessory drawing 10 VA, calculate the new total and explain why the 3-Amp fuse on the board will likely blow.

3. Resistive Loads: Electric Heat Strips

Electric "Heat Strips" are pure resistive loads. Their heat output (BTUs) is directly tied to the Voltage and Amperage they pull.

- **The Formula:** Watts = Volts times Amps and 1 Watt = 3.41 BTUs.
- **The Scenario:** A technician measures a heat strip pulling **20 Amps** on a **240V** circuit.
- **The Math:** 1. Calculate the total Wattage (240 times 20).

  2. Convert the Wattage to BTUs per hour (Watts times 3.41).

- **The Diagnostic:** If the unit is supposed to be a 10kW heater (10,000 Watts), is it performing at 100% capacity?

4. Solenoid Coils: Magnetic Force and Resistance

Solenoids use electromagnetism to open valves (like a reversing valve in a heat pump).

- **The Scenario:** A 24V solenoid coil is suspected of being "shorted." A healthy coil should have a resistance of roughly **15 to 20 Ohms**.
- **The Math:** Use Ohm's Law (I = V / R) to calculate what the Amperage should be if the resistance is 18 Ohms (24 \div 18).
- **The Diagnostic:** If the technician measures the current and finds it is **4.5 Amps**, calculate the actual resistance (24 \div 4.5). Based on this math, is the coil shorted (low resistance) or open (infinite resistance)?

5. Transformers: The Step-Down Ratio

Transformers change voltage, but the "Power In" must roughly equal the "Power Out."

- **The Formula:** V_p times I_p = V_s times Is (Primary Volts times Amps = Secondary Volts times Amps).
- **The Scenario:** A transformer steps 120V down to 24V. On the secondary (24V) side, the system is drawing **1.5 Amps**.
- **The Math:** Calculate the Amperage being drawn on the primary (120V) side.
- **Calculation:** (24 times 1.5) 120.
- **Trade Insight:** Why is the current so much lower on the high-voltage side? Use this math to explain why we use thin wires for thermostat controls but thick wires for the main power.

6. Run Capacitor: A run capacitor has a microfarad reading of 35mfd on the data nameplate. To be considered "good" it has to be tested using an electrical meter capable of testing microfarads or mfd. Also, on the data plate to be considered "good" it has to be +/- 5% of the 35 mfd. When tested it reads 25 mfd. Is this run capacitor "good"?

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 26 Electromagnetic Devices
- Chapter 27 Motor Controls

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 24 Systems & Components of domestic and commercial refrigerators
- Chapter 16 Electrical Control Systems

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 43 Air Source Heat Pumps Unit 45 Domestic Refrigerators & Freezers

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A 0721 Refrigeration Commercial Domestic Special Systems

A0785 A/C

A0791 Oil Burner Controls & Servicing

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** The student explains the specific role of a **differential controller** in a solar thermal system, justifying why the pump must only energize when the collector temperature exceeds the tank temperature.
- **Example:** When wiring a control transformer, students will be able to install and troubleshoot step-down transformers primary and secondary side connections.

VOG Trait: A Problem Solver

- **Project: The "Troubleshooting Gauntlet" Description:** Instructors introduce faults into a control system (e.g., a bad capacitor or relay). Students must use meters and ladder diagrams to identify the root cause and perform a professional repair.

<table>
<tr><th colspan="2">Priority Standard 10-8: Types of pipe and piping practices</th></tr>
<tr><td colspan="2">Big Idea(s):
1. Proper pipe selection and installation techniques ensure the safe and effective transport of fluids and gases throughout HVAC systems.</td></tr>
<tr><td colspan="2">Essential Question(s):
1. What are the different types of pipes used in HVAC, and how do the materials and techniques for installing pipes help keep our systems safe and efficient?</td></tr>
<tr><td colspan="2">Learning Outcomes</td></tr>
<tr><td>Students will know:</td><td>As evidenced by:</td></tr>
<tr><td>10-8.A Different types of piping and tubing used in HVAC systems
● ACR
● Nominal,
● K, L, M</td><td>1. Explain differences between ACR verse standard pipe.
2. Explain wall thickness K, L, M, and DW pipe</td></tr>
<tr><td>10-8.B Types of fittings
● Elbows
● Tees.</td><td>1. Explain differences between long way versus short way elbows.
2. Explain differences between Normal and street elbows.
3. Explain tee and sizing i.e: ¾ x ¾ x ¾ or ¾ x ¾ x ½ tee with reducing branch.</td></tr>
<tr><td>10-8.C Hangers used in HVAC systems</td><td>1. Explain closed cell pipe insulation</td></tr>
</table>

• **"U" clamps** • **Bell Hangers** • **Hanger strap** • **Uni-strut** • **Beam Clamps** • **Closed Cell insulation**	**2. Explain insulating tapes** **3. Explain reasons for insulation such as maintaining superheat** **4. Demonstrate proper insulating techniques** **5. Identify different hangers** **6. Explain Steel to copper electrolysis**
10-8.D Soldering and brazing alloys and compare their placement and purpose used in the HVAC/R industry such as: • **95/5, Silver content** • **Silver brazing rod**	**1. Explain the use of different soldering filler metals i.e. 50/50, 95/5 and silver solder etc.** **2. Explain the use of different brazing filler metals and melting temperatures**
10-8.E Soldering and brazing alloys	**1. Explain percent of silver content importance** **2. Explain concerns associated with flux** **3. Demonstrate proper soldering and brazing techniques**
10-8.F Effects of pressure drop in the refrigeration system	**1. Explain how pressure drops reduce system efficiency by causing energy to be used to move refrigerant** **2. Explain how pressure drops change refrigerant volatility**
10-8.G Refrigerant lines capacities and sizing for proper flow.	**1. Explain how refrigerant line size affects the amount of refrigerant moved** **2. Calculate capacities of refrigerant lines and determine sizing for proper flow.** **3. Explain how vapor refrigerant take more space than liquid** **4. Calculate total effective length of pipe runs for a given refrigeration system.**

	5. **Calculate amount of refrigerant in lines to arrive at the allowances for refrigerant charge.** 6. **Calculate pressure drop in liquid line risers to arrive at the correct liquid line size for a given system.** 7. **Size liquid and vapor lines for an installation of an air**
10-8.H Types of torches used in HVAC industry.	1. **Explain and demonstrating proper acetylene torch use** 2. **Explain and demonstrating proper oxygen/acetylene torch use** 3. **Explain parts of flame**
10-8.I Heat sink methods.	1. **Demonstrate how heat sinks are used to protect heat sensitive materials.**
10-8.J Various heat exchanger techniques.	1. **Demonstrate method of soldering cap tube to suction line for heat exchange.** 2. **Explain and identify commercially produced heat exchangers.**
10-8.K Vibration eliminators and components.	1. **Explain needs for vibration eliminators.** 2. **Demonstrate how to make a vibration eliminator that can be made with making loops of tubing.** 3. **Explain and identify manufactured vibration eliminators.**
10-8.L Effects of refrigerant velocity in refrigeration lines.	1. **Explain how refrigeration oil travels through the refrigerant system.** 2. **Explain how the velocity of the refrigerant keeps the heavier oil moving conditioning/refrigeration system.**

10-8.M Piping, Pipe Insulation and Connecting System Piping as it pertains to Solar Thermal installations. (Reference NABCEP 7.1-7.15) • **Copper Tube Installation** • **Plastic Piping Installation** • **Insulation Techniques** • **CSST Installation**	**(Reference NABCEP 7.1-7.15)** **1. Determine the extent of, and make allowances for expansion of pipe and its effect on hangers and the integrity of the pipe** **2. Determine type, length, and diameter of copper piping required** **3. Cut copper pipe to desired length** **4. Demonstrate solder copper piping connections** **5. Demonstrate test soldering fittings for leaks** **6. Determine type, length, and diameter of plastic piping required** **7. Cut plastic pipe to desired length** **8. Glue plastic piping connections** **9. Test glued fittings for leaks** **10. Determine type, diameter, and length of insulation required** **11. Demonstrate cutting insulation and install over piping and plumbing fittings** **12. Miter insulation ends, where appropriate** **13. Glue and sealing insulation joints, as required** **14. Select ultraviolet radiation protective method** **15. Protect insulation from ultraviolet degradation** **16. Determine type, length, and diameter of cost piping required** **17. Cut CSST pipe to desired length**

	18. Join CSST piping connections **19. Test CSST Tubing & fittings for leaks**
10-8.N Solar Thermal Piping: **(Reference: NABCEP 7.16-7.26)** • **Flashing** • **Penetrations** • **Sealants** • **Slope Strategy** • **Hangers** • **Standoffs** • **Connection** • **Underground Piping Methods** • **Connection of components**	**(Reference: NABCEP7.16-7.26)** **1. Determine type of pipe flashing to use for specific roof type** **2. Determine the area where pipe flashing will be installed** **3. Demonstrate roof penetrations** **4. Install pipe flashing and sealant** **5. Determine slope strategy of piping to avoid traps on horizontal runs** **6. Demonstrate slope piping to avoid traps in horizontal pipe runs** **7. Attach pipe hangers and supports** **8. Install stand-off hangers beneath piping on roof if needed** **9. Connect all system piping to water heater tank, collector, valves, pumps, etc.** **10. Determine under-ground piping method**

Link to Proficiency Scale 10-8

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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)

• Air conditioning and refrigeration (ACR) tubing • Brazing • Flare • Flare nut • Single flare • Soldering • Torch • Welding	• Flux • Nitrogen • Pipe schedule • Purging • Reamer • Silver brazing alloys • Solvent • Street fitting • Swaging • Thread sealant • Work hardened • Yoke • Annealing	• Carburizing flame • Capillary action • Flashback arrestor • Neutral flame • Oxidizing flame • Oxyacetylene • CPVC (chlorinated polyvinyl chloride) • PVC (polyvinylchloride) • Double flare • ABS(Acrylonitrile-butadiene-styrene) • Bending spring

Trade Math Crossover:

Piping Practices: Calculating "Take-Out" (Standard 10-8)

When installing refrigerant or gas piping, students must account for the length of the fittings themselves.

- The Scenario: A blueprint shows a pipe run of exactly 48 inches between two elbows. A 90-degree elbow has a "fitting allowance" (take-out) of 1/2 inch.
- The Math: To get a finished installation of 48 inches, how long must the student actually cut the piece of pipe? (48 - (0.5 + 0.5) [cite $_{s}$tart]= 47 inches).

Line Set Length/Fitting Allowance Calculations:

- When installing a duct less mini split a technician must consider the total liquid line length for proper refrigerant charging of the equipment for maximum efficiency. The manufactures data plate states that if liquid line exceeds 98.4 feet you must add an additional 1.08 ounces of refrigerant per every 5 feet of liquid line. When measured the liquid line measures 125 feet in total. What additional amount of refrigerant is needed if any?
- Calculating “Fitting Allowance” and “Take-offs” for various piping materials (Copper, Steel, Plastic)

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 4,6,7 Copper tubing, Soldering Brazing, Flame Cutting

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 8 Working with Tubbing

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 7 Tubing & Piping
- Unit 8 Leak Detection/ Evacuation

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A2113 Brazing & Cutting Metal

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example**: When preparing to solder a copper connection a student will gather necessary soldering materials and properly prepare a connection to be soldered and will take necessary safety precautions while on a job site while soldering.

Priority Standard 10-9: Effects of heat energy and pressure on the properties of matter	
Big Idea(s): 1. **Controlling pressure and understanding heat transfer are key to maintaining the balance and performance of refrigeration and climate systems.**	
Essential Question(s): 1. **What happens as water boils?** 2. **Why does water boil at a different temperature for sea level to high elevations?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
10-9. A Matter and define its properties listed below: ● **Solid** ● **Liquid** ● **Vapor**	1. **Classify matter according to its different states.** 2. **Explain how solids exert force down.** 3. **Explain how liquids exert force down and outward.** 4. **Explain how vapors exert force down, outward, and up.**
10-9.B The effects of a pressurized environment on matter: ● **Pressure** ● **Temperature**	1. **Explain how the atmospheric pressure at sea level is higher than that at high elevations.**
10-9.C The difference between heat and temperature:	1. **Identify the different scales of temperature measurements.**

● **Temperature is the measurement of molecular speed.** ● **Heat energy is a measurement of the speed of molecules and the number of molecules**	2. **Explain how heat is energy that is measured in British Thermal Units.**
10-9.D The direction and rate of heat flow.	1. **Demonstrate how heat flows from hot to cold.** 2. **Explain the difference in temperature affects flow and rate.**
10-9.E The three methods of heat transfer and summarize their placement in the HVAC/R industry.	1. **Identify radiant, conduction and convection heat transfer methods.**
10-9.F The reference points of temperature and identify a substance boiling point and freezing point.	1. **Identify temperature scales.** 2. **Identify and demonstrate how the boiling, freezing and absolute zero points are used as reference for these scales.**
10-9.D The direction and rate of heat flow.	1. **Explain how the changes in heat content affects the states of matter.** 2. **Explain how matter can exist as a solid, liquid and gas.**
10-9.E The three methods of heat transfer and summarize their placement in the HVAC/R industry.	1. **Explain how sensible heat causes temperature changes.**
10-9.F The reference points of temperature and identify a substance boiling point and freezing point.	1. **Identify how specific heat is different for amounts of sensible heat required to change the temperature of substances.**
10-9.g The direction and rate of heat flow.	1. **Identify how latent heat cannot be measured as states of matter changes.** 2. **Discuss how a fluid can be at temperature that when heat is added or removed the fluid will change state.**
10-9.K The difference between latent and sensible heat.	1. **Describe how latent and sensible heat affects substances as they change between states.**

10-9.L Heat/Cool storage.	**1. Explain how heat energy or the ability to remove heat energy can be stored.**
10-9.M Latent heat of fusion.	**1. Explain the removal of latent heat causing a substance to change from a liquid to solid.**
10-9.N Latent heat of vaporization.	**1. Explain the addition of latent heat causing a substance to change from a liquid to vapor.**

[Link to Proficiency Scale 10-9]

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- Tier 1: Common, everyday words (Basic communication).
- Tier 2: High-frequency academic words (Used across various subjects/trades).
- Tier 3: Low-frequency, domain-specific technical terms (The “Language of the Trade”).

Tier 1 (Everyday)	**Tier 2 (Academic)**	**Tier 3 (Technical/Trade)**
• Cold • Refrigeration • Ambient	• British thermal unit (Btu) • Kilojoule (kJ) • Physical states • Saturated condition • Saturation point • First Law of • Thermodynamics • Second Law of Thermodynamics • Specific heat • Absolute zero • Boiling point • Change of state • Radiation • Conduction • Convection • Insulator	• Ice Melting Equivalent (IME) • Latent Heat Of condensation • Latent heat of freezing • Latent Heat of melting • Latent heat of vaporization • Latent heat of sublimation • Subcooled • Superheat • Sensible heat • Latent heat • Natural convection • Forced convection

Trade Math Crossover:

Delta T Calcualtions:

- A section of baseboard has an entering water temperature of 200*F and an exiting water temperature of 180*F. What is the Δ T measurement?
- Calculating **Sensible vs. Latent heat** changes and measuring temperature differences across components.

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 9 Basic Thermal Dynamic Principles
- Chapter 10 Temp/Pressure

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 4 Energy/ Matter
- Chapter 5 Gasses

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 2 Matter & Energy

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0781 Refrigeration Fundamentals

A0006 HVAC Math

VOG Portfolio Collection Examples

VOG Trait: A Problem Solver

- **Example:** A student uses a Pressure-Temperature (P/T) chart to determine if a system is “Saturated.” They identify that a refrigerant is in a “subcooled” state and explain how this impacts the system’s ability to reject heat.

VOG Trait: A Critical Thinker

- **Example:** While students are working on a gas warm air furnace, they can take temperatures of the supply, return air temperatures, and calculate the heat rise.

Priority Standard 10-10: Relationship of pressures and fluids at saturation temperatures.

Big Idea(s):

1. **The relationship between pressure and temperature helps technicians accurately charge and assess refrigeration systems.**

Essential Question(s):

1. **When will an air conditioning system make you more comfortable and how?**

Learning Outcomes

Students will know:	*As evidenced by:*
10-10.A Relationship of pressures and fluids at saturation temperatures.	1. **Describe the relationship of pressures and fluids at saturation temperatures.** 2. **Explain how pressure affects the saturation temperature of refrigerants.**
10-10.B Relationship between temperature and pressure using the P/T Chart.	1. **Identify the relationship between temperature and pressure using the P/T Chart.** 2. **Demonstrate temperature and pressure using the P/T Chart.**
10-10.C HVAC Systems pressure.	1. **Explain how pressure is a relationship of force per unit area i.e. pounds per square inch PSI.** 2. **Explain how pressure can be expressed in absolute, which adds the weight of the atmosphere to gauge readings.** 3. **Explain and define pressure.**

10-10.D Atmospheric pressure	1. **Explain absolute pressure.** 2. **Explain how the atmosphere exerts pressure on the Earth.** 3. **Explain how the pressure changes at different elevations.** 4. **Explain atmospheric pressure as it relates to inches of mercury and microns.** 5. **Explain the standard condition at which the atmospheric pressure is 14.696.** 6. **Explain how barometric pressure is a measurement of the weight of the air.** 7. **Explain how barometric pressure changes with air conditions.**
10-10.E Gauge interpretation	1. **Explain the gauge that reads pressure above and below atmospheric pressure when atmospheric pressure is set at "0" psig.** 2. **Read a compound gauge and describe what is considered above atmospheric pressure and below atmospheric pressure.**
10-10.F Standard gauge pressure.	1. **Explain how gauges are set at zero.** 2. **Explain how pressure above the atmosphere increases readings.**
10-10.G Vacuum measured in inches of mercury absolute.	1. **Explain how 29.92" of mercury is an absolute pressure because it expresses the weight of the atmosphere.**
10-10.H Vacuum measured in micron.	**1. Explain how a micron is a more precise measurement of vacuum because 760,000 microns is equal to 29.92"hg.**
Link to Proficiency Scale 10-10	
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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Cold • Conduction • Convection • Radiation • Ambient	• British thermal unit (Btu) • Kilojoule (kJ) • Physical states • Refrigeration • Saturated condition • Saturation point • First Law of • Thermodynamics • Second Law of Thermodynamics • Natural convection • Insulator • Change of state • Absolute zero • Boiling point	• Ice Melting Equivalent (IME) • Latent Heat Of condensation • Latent heat of freezing • Latent Heat of melting • Latent heat of vaporization • Latent heat of sublimation • Subcooled • Superheat • Sensible heat • Specific heat • Latent heat • Forced convection

Trade Math Crossover:

1. Finding Saturation Temperature: A technician cannot measure the temperature *inside* a pipe with a thermometer; they must use a pressure gauge and "translate" that pressure into temperature using the P/T relationship.

- **The Scenario:** You are working on an R-404A reach-in freezer. Your low-side gauge reads **24 PSI**.
- **The Math:** Using a P/T chart, you find that 24 PSI for R-404A corresponds to a temperature of **-10°F**.
- **The Diagnostic:** This means the refrigerant is boiling inside the evaporator at -10°F. If the freezer box is at 10°F, calculate the **Temperature Difference (TD)** between the box and the coil (10 - (-10)). Is there enough of a "heat gradient" to pull heat out of the food?

2. Calculating Superheat (Evaporator Performance): Superheat is the heat added to a vapor *after* it has completely boiled off. It is the only way to ensure liquid refrigerant does not reach the compressor (which would destroy it).

- **The Formula:** Total Pipe Temperature - Saturation Temperature = Superheat
- **The Scenario:** * Your gauge reads **118 PSI** for R-410A (Saturation Temp = **40°F**).
    - Your pipe thermometer at the exit of the evaporator reads **52°F**.
- **The Math:** Calculate the Superheat (52 - 40).
- **The Code/Standard:** If the target superheat for this system is **10°F**, and your calculated value is **12°F**, is the system "starving" (too little refrigerant) or "flooding" (too much)?

3. Calculating Subcooling (Condenser Performance): Subcooling is the cooling of a liquid *below* its saturation point. It ensures that only 100% liquid reaches the expansion valve.

- **The Formula:** Saturation Temperature - Liquid Line Pipe Temperature = Subcooling
- **The Scenario:** * Your high-side gauge reads **318 PSI** for R-410A (Saturation Temp = **100°F**).
    - Your thermometer on the liquid line (small pipe) reads **92°F**.
- **The Math:** Calculate the Subcooling (100 - 92).
- **The Diagnostic:** If the manufacturer requires **10°F** of subcooling, and you only have **8°F**, calculate the "Subcooling Deficit." Does the system need more refrigerant?

4. Pressure and Altitude Adjustments: Atmospheric pressure changes with altitude, which affects gauge readings (PSIG).

- **The Data:** Atmospheric pressure at sea level is **14.7 PSI**. At 5,000 feet (Denver), it is roughly **12.2 PSI**.
- **The Math:** If a technician in Denver wants to find the "Absolute Pressure" (PSIA) of a tank reading **100 PSIG**, calculate the total (100 + 12.2).
- **The Physics:** Why does water boil at a lower temperature in the mountains? Use the relationship between lower pressure and lower saturation temperature to explain.

5. The "Glide" Challenge (Blended Refrigerants)

Many modern refrigerants (like R-407C) are "blends" of different gases that boil at different temperatures. This is called **Temperature Glide**.

- **The Data:** R-407C has a "Dew Point" (vapor) and a "Bubble Point" (liquid). At 75 PSI, the Bubble Point is **42°F** and the Dew Point is **53°F**.
- **The Math:** Calculate the "Total Glide" (53 - 42).
- **The Application:** Why must a 10th-grade technician always use the "Dew Point" column to calculate Superheat and the "Bubble Point" column to calculate Subcooling? Use the math to show the error margin if they used the wrong column.

Sample Superheat questions:

- A substance such as water has been heated to a temperature of 212.0*F. Additional heat was added to raise the water temperature to 232.0*F. The substance (water) has been superheated by how much?
- Using **Pressure-Temperature (P/T) Charts** to find saturation points for different refrigerants.

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 10 Temperature and pressure

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 5 Gasses.

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 2 Matter & Energy

OSHA.Gov:

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Apprenticeship Correlation

A0781 Refrigeration Fundamentals

A0006 HVAC Math

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** In a "Durable AI" assignment, the student fact-checks an AI-generated P/T chart that contains "hidden errors." They identify the incorrect pressure-to-temperature conversions and explain how those errors would lead to an incorrect refrigerant charge.

VOG Trait: Work Ready

- **Example:** While working with a refrigeration manifold gauge set a student will be able to recognize and explain the difference between the low and high side gauges.

Priority Standard 10-11: Vapor compression refrigeration cycle	
Big Idea(s): 1. **Mastering the refrigeration cycle allows technicians to diagnose, install, and repair cooling systems that are foundational to HVAC work.**	
Essential Question(s): **1. How does a refrigerator or air conditioner move heat to keep things cool?** **2.Why is each part of the refrigeration cycle (compressor, condenser, expansion device, and evaporator) important for making cooling happen?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
10-11.A The four major components of the vapor compression refrigeration system.	**1. Identify the four major components and explain the functions and refrigerant changes which occur in each component.** **2. Draw a simple refrigerant cycle diagram and label each of the basic components as well as the refrigerant lines.** **3. Place arrows on the diagram to show the direction of refrigerant flow.**
10-11.B Temperature / Enthalpy (T-H) Diagrams	**1. Describe the state and conditions of the refrigerant during a cycle.**

10-11.C Superheat affects the suction line gases; sub-cooling affects the refrigerant liquid line.	**1. Explain the importance of superheat and sub-cooling.** **2. Check and adjust superheat and sub-cooling to manufacturers' specifications.** **3. Write an essay on superheat, sub-cooling and how they are affected by the metering device.**
10-11. D Different types of metering devices and compare their function from the listed components below: • **capillary tubes** • **thermal expansion valve** • **automatic expansion valve** • **low side float** • **high side float** • **hand expansion valve** • **restrictor orifices** • **solid state expansion valve**	**1. Define types of metering devices:** **2. Identify various parts of the thermostatic expansion valve metering device from drawings.** **3. Adjust and size metering devices when and where appropriate.**
10-11.E Types of evaporators	**1. Identify different types of evaporators and their applications** **2. Explain the importance of proper coil air flow.** **3. Explain evaporator coil performance.** **4. Explain the size of the evaporator based on compressor capacities.**
10-11.F Types of compressors	**1. Identify and demonstrate open, semi-hermetic and hermetic compressors.**
10-11.G Methods of compression	**1. Identify different methods of compression including, reciprocating, rotary, scroll, screw and centrifugal Compressors.**

10-11.H The types of condensers	**1. Discuss air cooled and water-cooled condensers.** **2. Discuss static and forced draft designs** **3. Explain coil performance.**
10-11.I Proper air and water flow through condensers and evaporators	**1. Discuss reverse directional flow of water verse refrigerant.** **2. Adjusting for proper coil air flow.**
10-11.J Heat reclaim systems.	**1. Explain recovering heat from condensers to heat spaces.**
10-11.K Proper location of all compressor accessories: ● **crankcase heaters** ● **crankcase pressure regulating valve** ● **defrost timers** ● **driers/filters** ● **evaporator pressure regulating valves** ● **head pressure controls** ● **heat exchangers** ● **hot gas bypass** ● **low pressure controls** ● **low ambient controls, mufflers** ● **oil separators** ● **receivers** ● **solenoid valves** ● **suction filters** ● **vibration, eliminators** ● **check valves**	**1. Identify components from drawing accessories.**

• **water regulating valve** • **Relief valve.** • **accumulators**	
10-11.L The operation of the above listed and explain accessories.	**1. Define function of listed controls.**

[**Link to Proficiency Scale 10-11**]

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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Conduction • Convection	• Condensation • Evaporation • Reciprocating • Refrigerant • Compressor	• Evaporator • Condenser • Accumulator • Crankcase heater • Cooling tower • Filter drier • Flash gas • Off cycle • On cycle • Liquid receiver • Series connection • Temperature difference (td) • Thermostatic expansion valve • Basic refrigeration cycle • Metering device • Subcooled/Superheat • Suction line • High-pressure side

		• Hot Gas discharge line • Liquid line • Low-pressure side • Pressure-drop

Trade Math Crossover:

Vapor Compression Cycle: Enthalpy & Heat Transfer (Standard 10-11)

Students learn that the "Evaporator" doesn't "make cold"; it "removes heat."

- **The Scenario:** An evaporator coil is removing **30,000 BTUs** of Sensible Heat (lowering the temperature) and **12,000 BTUs** of Latent Heat (removing humidity).
- **The Math:** Calculate the **Total Heat Load** (30,000 + 12,000 = 42,000 BTUs).
- **The System Sizing:** If 1 Ton of cooling equals 12,000 BTUs, how many "Tons" of air conditioning is this system providing? (42,000 / 12,000 = 3.5 Tons).

Calculating Superheat and Subcooling Samples:

- A R22 refrigeration unit has a suction pressure of 68 psi and a saturation temperature of 40*F. The suction line temperature is 55*F. What is the superheat reading?
- Calculating **Superheat and Subcooling** to verify the correct mass-flow of refrigerant

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 11 Basic Refrigeration Cycle

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 6 Basic Refrigeration Systems
- Section 7 Refrigeration System Components

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 21 Evaporators and Refrigeration Systems
- Unit 22 Condensers
- Unit 23 Compressors

OSHA.Gov:

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Apprenticeship Correlation

A0781 Refrigeration Fundamentals

VOG Portfolio Collection Examples

VOG Trait: An Effective Communicator

- **Example:** The student narrates the "journey of a refrigerant molecule" through the four major components; Evaporator, Compressor, Condenser, and Expansion Device, clearly identifying where the state changes from liquid to vapor and where the pressure shifts from low to high.

VOG Trait: A Problem Solver

- **Example:** Students can locate the four basic refrigeration components while working on a refrigeration unit.

Priority Standard 10-12: Industry EPA standards for safety and environmental issues regarding refrigerants.	
Big Idea(s): 1. **Following EPA refrigerant guidelines protects the environment and ensures technicians work safely and within federal regulations.**	
Essential Question(s): 1. **Can you describe proper safety techniques that go with handling refrigerants?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
10-12.A Problems with mixing of refrigerants and the consequences of mixing refrigerants	1. **Explain the problems associated with mixing refrigerants and how to deal with mixed refrigerants.**
10-12.B Methods of determining when a recovery cylinder is full	1. **Determine when a recovery cylinder is full or will be full.**
10-12.C Problems with contaminants left in a refrigerant system after recovery	1. **Describe the problems associated with contaminants left in a refrigerant system after recovery and explaining what non condensable are and how they can affect a refrigeration system.**
10-12.D Manual pump down of a refrigeration system.	1. **Demonstrate manual pump down of systems.**
10-12.Isolate refrigeration components and explain the procedure.	1. **Describe how to isolate system components according to EPA regulations and demonstrate procedure.**
10-12.F Recycled and reclaimed refrigerant	1. **Describe system dependent and self-contained recovery equipment** 2. **Explain the differences between the 3 "R"s**
10-12.G EPA certification requirements: ● **Type I** ● **Type II** ● **Type III** ● **Universal**	1. **Explain differences in certification types.** 2. **Decide which type is right for them**

10-12.H Storage and handling of refrigerants and procedures.	1. **Explain safe refrigerant handling and applications.** 2. **Demonstrate safe refrigerant handling and application.**
10-12.I Refrigeration system recovery.	1. **Demonstrate proper system recovery with different methods available.**
10-12.K ASHRAE Refrigerant Safety Classifications of Refrigerants for Toxicity and Flammability.	1. **Explain the different classes of refrigerants, physical and chemical properties.**

Link to Proficiency Scale 10-12

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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Capture • Chlorine • Environmental Protection Agency (EPA) • Global warming • Hazardous waste	• De minimis • Universal certification • Active recovery • Atmospheric balancing • Reclaim • Recover • Recycle • Refrigerants	• Active recovery • EPA certification • Back seated valve • Ozone depletion potential (ODP) • Global warming potential (GWP) • Front seated valve • CFC • HFC • HCFC • Mid-seated valve • Low-loss fitting • Motor vehicle air conditioning (MVAC) • Passive recovery • Recovery cylinder • Clean Air Act (CAA) • Montreal Protocol • Pump down

Trade Math Crossover:

EPA Standards and Leak Rates (Standard 10-12)

As part of their EPA 608 certification, 10th graders must understand the environmental impact of refrigerant leaks.

- **The Data:** A commercial refrigeration system holds **60 lbs.** of refrigerant. Over 12 months, it required a "top-off" of **12 lbs.** to keep running.
- **The Math:** Calculate the **Annual Leak Rate** percentage (12 / 60 = 0.20 or 20%).
- **The Regulation:** If the EPA limit for this type of system is 10%, use the math to explain why the technician is legally required to repair the leak rather than just adding more gas.

Tare Weight Sample Questions:

- When using an empty recovery tank with a W.C (water capacity) of 47.7 lbs. and a tare weight of 27.5lbs, use the 80% rule and calculate how much total refrigerant can be added to the recovery tank.
- Applying the **80% Fill Rule** for recovery cylinders: (W.C. times 0.8) + Tare Weight

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599
- Chapter 13 Refrigerants
- Chapter 14 Zeotropic Blends
- Chapter 15 Refrigerant recovery

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545
- Section 4 Refrigerants

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5
- Unit 9 Refrigerant management

OSHA.Gov:
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0787 EPA Refrigerant Standards

VOG Portfolio Collection Examples

VOG Trait: An Effective Communicator

- **Example:** The student leads a peer discussion on the global impact of refrigerant leaks, connecting their technical skill in "leak-checking" to the larger community goal of protecting the ozone layer and reducing global warming.

VOG Trait: Work Ready

- **Example:** Students will be able to properly and safely use recovery equipment to evacuate a refrigeration system.

Priority Standard 10-13: Find employment in the HVAC trade and become a quality employee.

Big Idea(s):

1. **Success in the HVAC industry depends not only on technical skills but also on mastering professional behaviors and communication expected by employers. Through practice in shop settings and real-world experiences like Work-Based Learning (WBL), students develop the essential soft skills—such as reliability, teamwork, and professionalism—that make them valuable and employable members of the workforce.**

Essential Question(s):

1. **What skills and strategies are most effective in securing employment in today's competitive job market, and how can individuals demonstrate their value to potential employers?**

Learning Outcomes

Students will know:	*As evidenced by:*
10-13.A Work Based Learning	**1. Define expectations of each partner.** **2. Refer to the Work Study Guidelines for roles and expectations.** **3. Come to work every day on time.** **4. Is willing to take directions.** **5. Accomplish the task at hand.**
10-13.B Student contribution in the workplace.	**1. Formulate a list of what they can bring into the workplace and how each item may impact their job. School subjects; past experiences; self-concept and personality; needs, values and interests; knowledge skills and attitudes; career Priority Standards and plans.** **2. Demonstrate contributing to the success of a team.** **3. Self-assessment of skills using the above list as a guide.** **4. Explain how these skills would be valuable to the industry.** **5. Ability to read and interpret workplace documents.** **6. Demonstrate ability to respond in writing clearly and concisely.**

10-13.C Communication in the workplace.	**1. Discuss verbal and non-verbal communication. List ways negative nonverbal communication may be displayed.** **2. Role play ways of demonstrating effective verbal communication.** 3. **Contribute innovative ideas.** 4. **Works with initiatives and co-workers.** 5. **Working cordially with customers and co-workers.** 6. **Communicate effectively with co-workers and customers.**
10-13.D Interview Skills	**1. Outline and describe the three stages of an interview –greeting, exchange and parting.** **2. Role plays the stages of the interview.**
10-13.E Post interview	**1. Perform a follow-up activity after completion of the interview.** **2. Review interview.**
10-13.F Worksite guide.	**1. Discuss work site items: transportation; hours of work; absence and tardiness; conflict resolution; role of student, teacher, and workplace supervisor; dress code; job description; expectations**
10-13.G Feedback	**1. Provide feedback about work placement.** **2. Understand the guidelines for placement.**
Link to Proficiency Scale 10-13	

Trade Math Crossover:

1. Comparing Compensation Packages (The "Total Package" Math): A 10th grader must learn that the hourly wage is only one part of their value.

- **The Scenario:** You receive two job offers:
  - Company A: $22.00/hour, no health insurance, 40 hours a week.
  - Company B: $19.00/hour, but they pay $500/month toward your health insurance and offer a 3% 401k match.
- **The Math:** 1. Calculate the monthly gross pay for Company A (22 times 160 hours).

2. Calculate the monthly gross pay for Company B (19 times 160 hours) and then add the $500 insurance value.

3. Calculate the 401k match for Company B (3,040 times 0.03).

- **The Career Decision:** Which company offers a higher "Total Compensation" per month?

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2. Billable Efficiency (The "Quality Employee" Metric)

To be a "quality employee," you must generate more revenue for the company than you cost. Service managers track "Efficiency Ratings."

- **The Data:** You are paid for an 8-hour shift (480 minutes).
  - Travel time between jobs: 90 minutes
  - Shop time/loading truck: 45 minutes
  - Actual time spent fixing units (Billable Time): 345 minutes
- **The Math:** Calculate your Efficiency Percentage (345 div 480).
- **The Workplace Standard:** If the company goal is 75% efficiency, are you meeting the standard? What must you change about your day to reach that goal?

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3. The Cost of "Call-Backs"

A "quality employee" does the job right the first time. A "call-back" (returning to fix a mistake for free) is a major loss for the company.

- **The Scenario:** You spent 2 hours installing a motor, but you forgot to tighten the set-screw. The company has to send a senior tech back the next day to fix it.
  - Your original labor cost: $44 ($22/hr. times 2)
  - Senior tech's labor cost to return: $70 ($35/hr. times 2)
  - Lost opportunity (The $125/hr. the company *could* have billed if that senior tech was on a new job).
- **The Math**: Calculate the Total Loss to the company for this one mistake. How many hours must you work "error-free" to make up for that lost $195?

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4. Payroll Deductions (Net vs. Gross)

Understanding your paycheck prevents financial stress.

- **The Data:** Your gross weekly pay is $880.

- Federal Tax: 12%
- State Tax: 5%
- Social Security/Medicare: 7.65%

- **The Math**: 1. Calculate the total percentage being deducted (12 + 5 + 7.65).

2. Calculate the actual dollar amount of your "Take-Home Pay" (Net Pay).

- **The Professional Lesson:** Why is it important for an apprentice to budget based on their *Net* pay rather than their *Gross* hourly rate?

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5. Tool Allowance and Depreciation

Quality employees often invest in their own high-quality hand tools.

- **The Scenario:** You buy a high-end digital manifold for $600. You expect it to last for 3 years (150 weeks of work) before it needs replacing.
- **The Math:** Calculate the "Weekly Cost" of owning that tool (600 div 150).
- **The ROI (Return on Investment):** If this digital tool allows you to finish a charging task 10 minutes faster per job, and you do 15 jobs a week, how many minutes are you saving the company per week? Does the time saved justify the weekly cost of the tool?

VOG Trait: Work Ready

- **Example:** The student updates their Digital Portfolio with photos of their best sheet metal projects and electrical wiring labs, including a written reflection on how they applied feedback from a journeyman to improve their craftsmanship.

VOG Project: Mock Interview & Professional Portfolio:

- **Description:** Students participate in a three-stage mock interview (greeting, exchange, and parting) and develop a guide for the worksite that includes conflict resolution and dress code expectations. (VOG Alignment: Skilled Socially & Effective Communicator.)

CONNECTICUT TECHNICAL EDUCATION AND CAREER SYSTEM

HVAC

Grade 11

Grade 11 Curriculum

Priority Standard 11-1: Safety expectations at the school and work sites.	
Big Idea(s): 1. **Practicing professional behavior and safety builds a culture of trust and reliability in high-risk HVAC environments.**	
Essential Question(s): 1. **How does the culture of safety impact our lives outside of the classroom.**	
Learning Outcomes	
Students will know:	*As evidenced by:*
11-1.1 Proper clothing and safety equipment	1. **Wearing and describing reasons for proper clothing and safety equipment**
11-1.2 Effects of substance abuse on safety	1. **Giving examples to the reasons why technicians can't work safely while under the influence of any substance that interfere with coordination and decision making**
11-1.3 Proper storage and handling of • **Oxygen** • **Nitrogen** • **Acetylene bottles**	1. **Demonstrating safe use of high-pressure regulators.** 2. **Showing how to safely store and handle high-pressure gasses and the importance of keeping cap in place and strapping and storing cylinders in their upright position.** 3. **Explaining the dangers associated with pressurized gasses and tanks becoming projectiles.**

	4. Explain how to safely store and handle high-pressure gasses and the importance of keeping cap in place. **5. Explain the reasons for storing acetylene upright**
11-1.4 Precautions with servicing rotating components.	**1. Pointing out areas where personal injury could occur due to rotating parts while servicing a refrigeration system.** **2. Describe Dangers of being caught in rotating components & using precautions when working rotating components**
11-1.5 Safety concerns related to servicing refrigeration system.	**1. Exhibiting proper eye safety during service/testing procedures** **2. Identifying and listing the components in refrigeration systems that are a concern due to operating temperature extremes.**
11-1.6 Dangers of working on energized live equipment.	**1. Appraising the inherent dangers of working on energized/live/operating equipment.** **2. Observed electrical safety precautions and the safe use of electrical testing instruments during service/testing procedure.**
11-1.7 Unsafe driving consequences.	**1. Predicting the outcome of a DUI, speeding violation or other traffic violation on their employability, cost to employers and themselves.** **2. Identified the reasons why technicians cannot work safely while under the influence of any substance that interferes with coordination and decision making.** **3. Researching why the insurance companies of employers will require driving record**

[Link to Proficiency Scale]

Tiered Vocab- HVAC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:

- Tier 1: Common, everyday words (Basic communication).
- Tier 2: High-frequency academic words (Used across various subjects/trades).
- Tier 3: Low-frequency, domain-specific technical terms (The “Language of the Trade”).

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Air-purifying respirator • Confined space • lockout/tagout (LOTO) • Occupational Safety and Health Act (OSHA) • Personal protective equipment (PPE) •	• Hazard Communication Standard (HCS) • Pictogram hazard • Safety data sheet (SDS) • Stationary refrigerant Detector • Supplied-air respirator • Signal word • Worker’s compensation	• Globally Harmonized System • (GHS) • ASHRAE Standard 34 • Authorized person • Competent person • Qualified person • Designated person •

Trade Math Crossover: Examples

1. Fall Protection: Calculating Total Fall Distance

In the 11th grade, technicians are often on-site for "Intermediate Application" projects, such as rooftop unit (RTU) diagnostics. Before clipping into an anchor, you must calculate if your fall arrest system will actually stop you before you hit the lower level.

- The Components:
  - Lanyard Length: 6 feet
  - Deceleration (Shock Absorber) Distance: 3.5 feet
  - Harness Stretch/D-ring Slide: 1 foot
  - Safety Factor (Clearance): 3 feet
- The Math: Total Fall Distance = 6 + 3.5 + 1 + 3 = 13.5 feet.

- The Safety Check: If you are working on a mezzanine that is 12 feet above the shop floor, will this equipment save you?
    - Calculation: 12 ft (height) < 13.5 ft (required distance).
    - Conclusion: No. You would hit the floor before the shock absorber fully deployed. You must use a shorter lanyard or a self-retracting lifeline (SRL).

2. Ladder Safety: The 4-to-1 Ratio and Extension Rule

Standard 11-1 reinforces the legal "setback" requirements for extension ladders to prevent tipping or sliding.

- The Scenario: You need to access a roof that is 24 feet high.
- The Rule: The ladder must extend 3 feet past the roof edge for a safe transition.
- The Math (Total Length): 24 feet (roof) + 3 feet (extension) = 27 feet of ladder.
- The Math (Setback): Using the 4-to-1 Safety Ratio, calculate the distance the base must be from the wall.
    - Calculation: 24 feet (vertical height) div 4 = 6 feet.
- The Verification: If the base is 8 feet away, the ladder is too shallow and could slide out; if it is 4 feet away, it is too steep and could tip backward.

3. Electrical Safety: The 80% Circuit Breaker Rule

11th graders perform "Start-ups" on gas and electric systems. Safety expectations include ensuring the equipment does not "nuisance trip" the breaker, which can lead to emergency situations.

- The Rule: A circuit breaker should not be loaded to more than 80% of its rating for continuous loads (standard for HVAC motors).
- The Scenario: You are installing a furnace with a blower motor that draws 14.2 Amps. The circuit has a 15-Amp breaker.
- The Math: * Max Safe Load: 15 Amps times 0.80 = 12 Amps.
- The Safety Diagnostic: Since 14.2 Amps > 12 Amps, this installation violates safety standards for continuous operation. You must upgrade to a 20-Amp circuit to prevent the breaker from overheating.

4. Rigging and Lifting: Center of Gravity

As part of "Inside and Outside Production" (Standard 11-1), juniors may assist in rigging equipment for cranes.

- The Scenario: You are lifting a heavy commercial condenser that weighs 1,200 lbs. The internal compressor (the heaviest part) is located on the far-right side, shifted 2 feet off-center.
- The Math: If you use two slings, one at each end, and the unit is 8 feet long:
  - Center of Gravity (CG): 2 feet from one end.
  - Weight Distribution: The sling closest to the compressor will carry a larger percentage of the weight.
  - Calculation: Sling A (near CG) = $1,200 times (6/8) = 900 lbs. Sling B (far from CG) = 1,200 times (2/8) = 300 lbs.
- The Safety Check: If you used two 500-lb rated straps, Sling A would snap, causing a catastrophic drop.

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5. Confined Space: Oxygen Displacement

Safety at the work site includes monitoring the atmosphere when soldering in confined spaces.

- The Scenario: You are brazing in a small mechanical closet (8' x 8' x 8' = 512 cubic feet). You are using Nitrogen to purge the lines.
- The Math: If you accidentally release 100 cubic feet of Nitrogen into the room:
  - Current Oxygen: Normally 21% (512 times 0.21 = 107.5 cu ft).
  - New Volume: Total volume remains 512, but Nitrogen has pushed out 100 cu ft of "air."
  - New Oxygen %: (107.5 - [100 times 0.21]) div 512 = ~16.8%.
- The Safety Threshold: OSHA states that an environment is "Oxygen Deficient" below 19.5%. The math proves this closet has become a deadly confined space.

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6. Sample Problems:

- You are part of an 11th-grade Work-Based Learning (WBL) crew sent to a commercial job site to install a rooftop exhaust fan. The roof edge is 24 feet high. What is the distance from the wall and the base of the ladder?

Suggested Resources
Heating & Cooling Essentials: ISBN 13: 9781631260599 • Chapter 3. Safety Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545 • Section 1, Chapter 2. Basic Principles for Construction, 3rd Edition (Residential Construction Academy) 3rd Edition ISBN-13: 978-1111307189 • Chapter 3. Job Safety OSHA.Gov: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593
Apprenticeship Correlation
OSHA 30: A0099
VOG Portfolio Collection Examples
VOG Trait: Work Ready • **Example:** The student maintains an up-to-date **OSHA-10 or OSHA-30** card and carries it at all times. They demonstrate "Job-Site Readiness" by conducting a daily PPE inspection of their own gear and their teammates' gear before starting a high-risk task, such as working near high-voltage panels or with combustible fuel gases. • **Example:** A student demonstrates professional "soft skills" by maintaining a consistent attendance record and a clean, organized service vehicle/station, treating the school shop with the same respect required by a private HVAC contractor. **VOG Trait: An Effective Communicator** • **Example:** Before beginning a complex group lab, the student leads a **"Tailgate Safety Meeting."** They clearly outline the specific hazards of the day (e.g., refrigerant handling or ladder safety)

and ensure every team member understands the emergency shut-off locations and evacuation routes.

- **Example:** The student can articulately explain the legal and financial consequences of a safety violation to a peer, describing how a single accident impacts insurance rates, company reputation, and, most importantly, human life.
- **Example:** Students can present images of themselves wearing proper PPE for different tasks.

VOG Trait: A Critical Thinker

- **Example:** The student evaluates a work-site scenario involving a confined space or a roof-top unit. They determine if the standard PPE is sufficient or if additional measures—such as a fall-protection harness or specialized ventilation—are required based on **OSHA Subpart D and M** standards.

<table>
<tr><th colspan="2">Priority Standard 11-2: Knowledge of basic electricity, electrical circuits and AC electric motors</th></tr>
<tr><td colspan="2">Big Idea(s):
1. Applying knowledge of circuits and motors allows technicians to power, control, and troubleshoot HVAC systems efficiently.</td></tr>
<tr><td colspan="2">Essential Question(s):
1. How does the flow of electric current impact the way we use energy in everyday life?</td></tr>
<tr><td colspan="2">Learning Outcomes</td></tr>
<tr><td>Students will know:</td><td>As evidenced by:</td></tr>
<tr><td>11-2.1 Applications of magnetism in electricity</td><td>1. Define magnetic theory
2. Exhibit the use of the appropriate meter to check basic electrical components.</td></tr>
<tr><td>11-2.2 Low voltage wiring and controls required for heating and cooling equipment to operate.</td><td>1. Exhibit the wiring of a complete low voltage heating and air conditioning control circuit to accommodate a heating furnace with a split cooling system.
2. Show how to program a programmable thermostat for heating/cooling including set-up and setback modes.
3. Detect and compare single- and three-phase voltage and current</td></tr>
<tr><td>11-2.3 Various three phase electric motor theories
● Electronically controlled motor
● Variable-speed motor</td><td>1. Define the significance of power factor.
2. Give examples for starting and over current protection components associated with three-phase motors.</td></tr>
</table>

• **Three-phase motor** • **Identify Wye and Delta motors**	**3. Explain the operation and application of motors and supporting what problems could happen and where they would have occurred.** **4. Explain electric motor theory (i.e., magnetism, electromotive force, etc.).** **5. Explain operation and application of: different three phase motors**
11-2.4 Types of electrical loads; Capacitive, Inductive, resistive	**1. Define the significance of power factor.** **2. Give examples for starting and over current protection components associated with three-phase motors.** **3. Explain the operation and application of motors and supporting what problems could happen and where they would have occurred.** **4. Explain electric motor theory (i.e., magnetism, electromotive force, etc.).** **5. Explain operation and application of: different three phase motors** **6. Identify the relationships of voltage and amperage in different loads.**
11-2.5 Principles of solid-state switching devices	**1. Discuss how solid-state devices control flow of electrons without mechanical switches that ware out due to friction and sparks** **2. Identify principles of solid-state switching devices**
11-2.6 Electricity production and distribution	**1. Explain how magnetically produced electricity is transformed and distributed from plants to users through electrical grid**

	2. Explain how a wire passed through a magnetic field will have a voltage created in it
11-2.7 The differences in Wye (Y) and Delta (D) distribution systems	**1. Identify the different wiring of Wye and Delta and explaining the flow of electrons through the Wye and Delta systems** **2. Identify the different voltages produced in Wye or Delta systems**
11-2.8 Operation and application of motors	**1. Identify different motor types and uses, small axial fans, squirrel blowers, compressors etc.** **2. Explain proper horsepower of replacement motors**
11-2.9 Starting components associated with single-phase and three-phase motors ● **centrifugal switch** ● **current coil relay** ● **potential relay** ● **PTC relay**	**1. Identify single phase starting components** **2. Identify contactors and motor starters**
11-2. Detailed instructions for wiring circuits interpretation.	**1. Identify electrical switch and load symbols used in diagrams.** **2. Draw basic electrical circuits that demonstrate an understanding of switches controlling loads**

Link to Proficiency Scale

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CTECS HVAC

Tier 1 (Everyday)	**Tier 2 (Academic)**	**Tier 3 (Technical/Trade)**
• Alternating current(ac) • ampere • atom • brushes • conductor • current • electricity • Direct current(dc) • Electricity • Electron • Ohm’s law • Switch	• AWG • Closed • Circuit • Circuit breaker • Dielectric • Electrical circuit • Electrical load • Fuse • Grounding • Open circuit • Closed circuit • Ground fault interrupter • Load • Resistance • Short circuit • Single phase • Three phase • Watt’s law	• Bonding • Brushes • Capacitance • Capacitor • Electromagnet • Electromagnetism • Farad(F) • Induced magnetism • Induction • Volt-amps • Voltage drop • coulomb • Electromotive force (emf)

Trade Math Crossover:

1. Advanced Electrical Logic (Standard 11-2)

Juniors must calculate the specific power requirements for multi-stage heating and cooling systems to ensure circuit protection.

- **The Scenario:** A high-efficiency furnace has a blower motor (6.2 Amps), an inducer motor (1.8 Amps), and a 24V control circuit (0.5 Amps).
- **The Math:** 1. Calculate the **Total Running Amperage** (6.2 + 1.8 + 0.5 = 8.5 Amps).

  2. Using the **National Electrical Code (NEC)** standard, calculate the **Minimum Circuit Ampacity (MCA)** by multiplying the largest motor by 125% and adding the others (6.2 times 1.25] + 1.8 + 0.5 = 10.05 Amps).

- **The Safety Check:** If the circuit is protected by a 15-Amp breaker, what is the "Safety Margin" in Amps?

Sample Problems:

- If a circuit has a resistance of 5 ohms and voltage supplied is 240 volts what would the amperage total?

Suggested Resources

Resources to compliment learning- Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 23 What is Electricity

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 13 Electrical Power

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 18 Application of motors
- Unit 19 Motor Controls

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0782 Electric Fundamentals

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** The student differentiates between the starting and running characteristics of various AC motors (e.g., PSC vs. ECM). They justify the use of an ECM motor in a high-efficiency system based on its ability to maintain constant CFM regardless of static pressure.

VOG Trait: A Problem Solver

- **Example:** When a blower motor fails to start, the student uses a multimeter to perform "voltage drop" testing. They identify that the issue is not the motor itself, but a pitted contactor, saving the customer the cost of an unnecessary motor replacement.

VOG Trait: An Effective Communicator • **Example:** Students can create then present posters which outline the distinct types of starting components used for compressors.

Priority Standard 11-3: The use of building codes and manufacturers' installation instructions on current production jobs	
Big Idea(s): 1. **Understanding and following codes and manufacturer instructions ensures systems are installed safely, legally, and to industry standards.**	
Essential Question(s): 1. **Who writes the codes used for installing mechanical systems or building structures? Why are codes important? Who enforces the use of codes?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
11-3.A Codes for- • **Safe installations** • **Energy efficiency** • **Proper venting of combustion gases** • **Fresh air considerations**	1. **Explain the need for building codes to assure safety throughout our industry when installing, servicing, or repairing HVAC equipment.** 2. **Demonstrate an awareness of their limitations, altogether ensuring a safe alteration to building structure while cooperating with others on site.**
11-3.B The names of the three model codes • **BOCA** • **SBCCI** • **ICBO**	1. **Explain code models.**

11-3.C Codes and standards for the applicable area, locality, and state.	**1. Identify necessary codes from the International mechanical code when regulations are not specified otherwise.** **2. Explain CT code models used in most area**
11-3. D Relationship between codes and manufacturers' installation instructions.	**1. Prepare to install or repair HVAC equipment, referring to the manufacturers' installation instructions.** **2. Give examples of the local building and energy codes when directed to do so.** **3. Explain how local codes and manufacture instructions super cede each other when the other is safer.** **4. Explain enforcement of codes by building inspectors** **5. Analyze building plans to help prepare for the obstacles which may be encountered during system installation**
11-3.E How to identify pertinent standards published by AGA, AMCA, ANSI, ARI, ASHRAE, IED, ISO, SMACNA, and UL.	1. Describe about organizations which investigate and lobby for manufacture, installation, and service standards
11-3.F The methods for adapting a Solar Thermal System Design (Reference NABCEP 3.1-3.9)	(Reference NABCEP 3.1-3.9) 1. Determine active direct system components' location and system layout and configuration 2. Determine active indirect system components' location and system layout and configuration 3. Determine passive direct system components' location and system layout and configuration

	4. Determine passive indirect system components' location and system layout and configuration 5. Determine solar pool system components' location and system layout and configuration. 6. Apply for building permits. 7. Estimate time, materials, tools, and labor required for installation. 8. Determine installation sequence to optimize use of time and materials. **9.** Inspect all provided system components for damage prior to installation
11-3.G Mechanical/Plumbing Equipment and other components onto Solar Thermal Systems: **Reference NABCEP: 8.1-8.5** • **System components** • **Location of components** • **System monitoring components** • **Heat exchanger** • **Heat exchanger fluids**	Reference NABCEP: 8.1-8.5 1. Determine system plumbing, valves and other components required, (This includes the following: valves, air vent, check, drain, auto drain down, expansion tanks, flow control, isolation, diverting, solenoid, mixing, anti-scald, pressure relief, temperature pressure relief, vacuum relief, balancing, freeze, etc. as well as the following monitoring components; flow meter, temperature gauge, pressure gauge, etc.) 2. Determine location of plumbing valves and other components 3. Install system plumbing valves and monitoring system components as specified in component manufacturers or solar manufacturer's installation manual and schematic. 4. Determine the heat exchanger location Install heat exchanger and heat exchanger

	fluids as specified in manufacturers installation manuals and schematics

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Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Service • Specialty • certification	• Building inspector certification • Energy auditor estimator • HVACR designer.	• HVACR drafter • HVACR engineer Installation • RSES (Refrigeration Service Engineers Society)

Trade Math Crossover:

1. Gas Pipe Sizing (The Longest Length Method)

The **International Fuel Gas Code (IFGC)** requires gas pipe sizing based on the total BTU load and the distance from the meter.

- **The Scenario:** A new production home has a 100,000 BTU furnace located 60 feet from the meter. You are using Schedule 40 Black Iron pipe.
- **The Data:** According to the IFGC sizing table, 1/2" pipe can carry 72,000 BTUs at 60 feet, while 3/4" pipe can carry 151,000 BTUs at 60 feet.
- **The Math:** If the homeowner decides to add a 30,000 BTU gas fireplace to the same line, calculate the new total BTU load.

- **The Application:** Does the existing 3/4" pipe have enough capacity for both appliances (100,000 + 30,000)? If the fireplace is at the end of a 90-foot run, use the table to determine if you must upsize the main trunk to 1".

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2. Manufacturer-Specific Venting (Equivalent Length)

Manufacturers specify the maximum length of PVC vent pipe a furnace can handle. Each elbow added to the line creates "friction loss" equivalent to several feet of straight pipe.

- **The Data:** A high-efficiency furnace allows for **100 equivalent feet** of 2-inch PVC.
  - Each 90-degree elbow = 5 equivalent feet.
  - Each 45-degree elbow = 2.5 equivalent feet.
- **The Scenario:** A production job requires a vent run that is 70 actual feet long, with four 90-degree elbows and two 45-degree elbows.
- **The Math:** Calculate the **Total Equivalent Length**:
  - 70 + (4 times 5) + (2 times 2.5) = ?
- **The Decision:** Is this installation within the manufacturer's 100-foot limit? If not, the student must calculate if switching to 3-inch pipe (which has a 150-foot limit) will solve the problem.

---

3. Condensate Pump Head Pressure

The IMC requires condensate to be disposed of in an approved manner. If a floor drain is not available, a pump must be used. Manufacturers rate these pumps by "Lift" or "Head Pressure."

- **The Scenario:** A condensate pump is rated to lift water **20 vertical feet**.
- **The Physics:** For every 1 foot of vertical lift, the pump must overcome **0.433 PSI** of pressure.
- **The Math:** 1. Calculate the pressure the pump faces at its maximum 20-foot lift.

2. If the pump is pushing water up 12 feet and then 40 feet horizontally, and the manufacturer says to add 1 foot of "lift" for every 10 feet of horizontal run, calculate the "Effective Lift."

- **The Application:** Will a 20-foot rated pump work for this specific 12' vertical / 40' horizontal installation?

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4. Electrical: Minimum Circuit Ampacity (MCA)

Manufacturer's instructions provide the MCA to ensure the technician sizes the wire correctly according to the **National Electrical Code (NEC)**.

- **The Data:** An outdoor heat pump nameplate lists an **MCA of 28.5 Amps**.
- **The Code (NEC Table 310.16):** * 12-gauge wire is rated for 25 Amps.
  - 10-gauge wire is rated for 30 Amps.
- **The Math:** Calculate the "Safety Buffer" remaining if you use 10-gauge wire (30 - 28.5).
- **The Voltage Drop:** If the unit is 150 feet from the electrical panel, the code recommends a wire size that limits voltage drop to 3%. If the drop is calculated at 4.2% for 10-gauge, use math to determine if you must "upsize" to 8-gauge wire despite the manufacturer's minimum.

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5. Combustion Air Louver Sizing

If a furnace is in a confined space, the IMC/IFGC requires two openings to the outside. The "Free Area" of these louvers is critical.

- **The Rule:** 1 square inch of "Net Free Area" for every 4,000 BTUs of input.
- **The Scenario:** You have two 50,000 BTU water heaters in a small room (100,000 total BTUs).
- **The Math:** 1. Calculate the required Net Free Area (100,000\div 4,000).

2. Most metal louvers only provide **75%** free area (the rest is the metal frame/slats).

- **The Final Calculation:** If you need 25 square inches of free area, what size louver (e.g., 6"x6" or 8"x8") must you actually buy to ensure the *open* space equals 25 square inches?

Apprenticeship Correlation

A0729: International Mechanical Code

A0730: Related Codes and Standards:

NFPA Book

WWW.ICCSAFE.org

WWW.SMACNA.ORG

Related Codes and Standards

VOG Portfolio Collection Examples

VOG Trait: An Effective Communicator

- **Example:** A student acts as a "Lead Technician" during a shop inspection, using the manufacturer's "Startup Checklist" to explain to the instructor (acting as the inspector) exactly how the gas pressure and temperature rise were verified against the equipment's data plate.
- **Example:** The student can translate complex code language (e.g., "Combustion Air Requirements") into simple, clear instructions for a junior peer or a homeowner, explaining why a specific louvered door or fresh air intake is required by law.
- **Example:** Students can highlight and present proper installations of production jobs following local building codes.

VOG Trait: Work Ready

- **Example:** The student demonstrates the habit of "Reading the Manual First." Before unboxing a new thermostat or zone controller, they locate the wiring diagram and configuration settings in the instructions, preventing "blown" fuses or fried control boards caused by trial-and-error.
- **Example:** The student maintains a digital library of commonly used IOMs and Code sections in their **Digital Portfolio**, proving to employers they have the research skills needed for modern, high-tech HVAC production jobs.

VOG Project:

- Code Compliance Inspection Report: Description: Students analyze a "production job" installation and write a report comparing it against the International Mechanical Code and manufacturer's installation instructions. (VOG Alignment: Critical Thinker & Effective Communicator.)

Priority Standard 11-4: Calculate total heat gain/loss for the proper sizing of heating/cooling equipment.	
Big Idea(s): 1. **Accurate load calculations are essential for selecting properly sized HVAC equipment that delivers energy efficiency and comfort.**	
Essential Question(s): 1. **Can you explain the heat values and how to apply them to a blueprint?** 2. **Would it be possible to size a job by looking at structure design?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
11-4.A Heat transfer tables ("U," "K," "R").	1. **Define "U""K""R" value needed for heat/cool gains and loss calculations** 2. **Select and applying resistance to heat flow, ("R"), ("U") values to their respective areas for load calculations**
11-4.B Heat gain/loss calculation to select properly sized HVACR equipment	1. **Select properly sized HVACR equipment for applications from calculations.**
11-4.C Blueprints – size rooms, etc. for the breaking down values needed for the load calculation.	1. **Apply trade related math through calculating necessary net areas of the building structure, subject to heat gain/loss.**

• **Net exposed wall area** • **Ceiling area** • **Floor area** • **Windows (glass area)** • **Door area**	**2. Calculate infiltration of windows and doors for heat loss** **3. Validate heat loss and heat gain specific heat values times their design temperature difference for heating and cooling to calculate hourly sensible gains and losses**
11-4.D Tables of specific heat values, latent heat, and heat of respiration.	**1. Explain use of design conditions for different climates**
11-4.E Vapor barriers.	1. Explain vapor barriers and their effect on load calculations
	1. Determine design data from given blueprint

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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Crawlspace • Insulation	• Outdoor design temperature (ODT) • Manual j • Total heat loss • Sustainable • Indoor design temperature • (IDT) • Heat gain • Heat lag • Heat leakage • Heat load	• Emissivity • Heat transfer • multiplier • (HTM) • thermal • conductance • (C-value) M) • thermal • conductivity • (K-value) • thermal

	• Heat loss • Heat transfer rate	• resistance • (R-value) • thermal • transmittance • (U-value) • Total cooling load

Trade Math Crossover:

Manual J: Total Heat Gain/Loss (Standard 11-4)

This is one of the most rigorous math standards, requiring students to calculate "Heat Transfer" based on the thermal resistance (R-value) of a building.

- **The Formula:** Q = U times A times Δ T (Heat Loss = 1/ R-value \times Area times Temperature Difference).
- **The Scenario:** A room has a 10' x 20' exterior wall with an R-value of 13. The outside temperature is 0°F, and the inside target is 70°F.
- **The Math:** 1. Calculate the Area (10 times 20 = 200 sq ft.).

2. Convert R-value to U-factor (1 div 13 = 0.077).

3. Calculate the BTUs lost per hour (0.077 times 200 times 70 = 1,078 BTUs hr.).

- **The Engineering Challenge:** If the room has four such walls and a ceiling losing 2,000 BTUs/hr., what is the total heating capacity needed?

Sample Math Problems:

- If you perform a heat gain on a building at the unit size is 3.5 tons, how many btu’s is the unit, and how many cfm are required when sizing the ducts?

- Calculating the square footage of "Building Envelopes" (walls, windows, doors) to determine BTU loads.

Suggested Resources

Wright Soft 7 Load Calculation software

Wright Soft University

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 50 Understanding heat Loads/ System thermal dynamics
- Chapter 37 Heating & Cooling Loads
- Chapter 45 energy management
- Chapter 46 Conservation

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 42 Heat gains Heat losses

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0790 Forced air Heating & Cooling

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** Using "Manual J" principles, the student calculates the total heat loss for a residential room. They must account for "R-values" of insulation and window orientation to determine the precise BTU requirements, ensuring the equipment is neither undersized nor oversized.

VOG Trait: A Problem Solver

- **Example:** The student uses a **duct calculator** to design a trunk-and-branch system. When the calculated friction loss exceeds the blower's capability, they "re-size" the ductwork layout to ensure quiet and efficient airflow

VOG Trait: An Effective Communicator

- **Example:** Students can present drawings of floor plans and even print outs of wright soft calculations from school software.

Priority Standard 11-5: Airflow principles and design of air handling equipment.	
Big Idea(s): 1. **Airflow design directly affects system performance and indoor comfort, making it a critical part of HVAC system planning and maintenance.**	
Essential Question(s): 1. **How can you determine if a heating or air conditioning system was installed correctly?** 2. **How would a tech lay out a trunk line for the equipment you must install?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
11-5.A Ductwork pressures	1. **Explain duct pressures** 2. **Explain how ductwork pressures affect equipment, ductwork, and register/diffuser sizing**
11-5.B Air distribution system.	1. **Demonstrate ability to use duct calculator to find correct duct size, velocity, CFM, and friction loss**

	2. Demonstrate how to use a duct work calculator to properly size an air distribution system.
11-5.C Layout of duct systems.	**1. Draw layout of return and supply systems.**
11-5.D Trunk and branch ducts design	**1. Demonstrate ability to size trunk and branch ducts by equal friction method.**
11-5.E Registers, grilles, and diffusers.	**1. Demonstrate ability to size supply registers, return grilles, and diffusers.**
11-5.F Types of fans/blowers	**1. Explain different types of fans/blowers**
11-5.G Proper rotation of blowers	**1. Demonstrate the ability to check for proper rotation of single and three phase blowers and correct if rotation is incorrect**
11-5.H Fans/blowers' performance.	**1. Demonstrate the ability to check fans/blowers' performance.**
11-5.I Amp draws and fan speed adjustment	**1. Check amp draws and make fan speed adjustment**
11-5.J Fresh air controlling devices	**1. Explain the reasoning for supplying as well as monitoring and adjusting fresh make up in LEAD constructed buildings**

Link to Proficiency Scale

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Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Flow • Fan • Duct	• Butterfly damper device • Friction rate • Friction loss	• External static pressure (ESP) • Device pressure losses

• Elbow • Grille • Register • Whole house fan	• Forced draft • Gable fan • Induced draft • Primary air • Effective length • Duct board • Diffuser • Unvented attic • Vented attic	(DPL) • Multiple-blade damper • Total effective length • (TEL) • Total pressure drop • Return air duct • Starting collar

Trade Math Crossover:

Airflow Principles and Duct Design (Standard 11-5)

Students use the **Affinity Laws** and **Static Pressure** calculations to ensure air reaches every room.

- **The Scenario:** A technician measures the **Total External Static Pressure (TESP)** of a system and finds it is 0.8" w.c. (water column). The manufacturer's data plate says the limit is 0.5" w.c.
- **The Math:** 1. Calculate the "Pressure Overage" (0.8 - 0.5 = 0.3 or 60%).

2. Use the **Fan Laws** to predict the result: If you double the static pressure, the power required by the motor increases by the *cube* (2^3 = 8 times the power).

- **The Diagnostic:** Explain why this high pressure will lead to motor failure and calculate the necessary increase in duct diameter to drop the pressure.

Sample CFM Problems:

- If an 8 ich duct is rated for 150 cfm how many branch runs are needed for a 2-ton system?
- Calculating **CFM (Cubic Feet per Minute)** requirements based on a room's sensible heat load.

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 29 Ductwork

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 29 Air Distribution

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 37 Air Distribution / Balance

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Online Ductulator (Version 1)

Online Ductulator (Version 2)

Apprenticeship Correlation

A0790 Forced air Heating & Cooling

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** A student uses a **manometer** to measure Total External Static Pressure (TESP) across an air handler. They compare their reading to the manufacturer's data plate and identify that the static pressure is too high (e.g., 0.8" w.c. vs. a limit of 0.5" w.c.), concluding that the ductwork is undersized or the filter is severely restricted.
- **Example:** The student evaluates the "Fan Laws," explaining how doubling the fan speed doesn't just double the airflow but actually triples the pressure and cubes the horsepower required, demonstrating a deep understanding of the energy costs of improper design.
- **Example:** Students can present a duct drawing they created which shows sizes and cfm totals for each room.

VOG Trait: An Effective Communicator

- **Example:** The student explains the concept of "Velocity" vs. "Volume" to a peer, using the analogy of a garden hose to show how shrinking the duct size increases the speed of the air (causing noise) but may actually decrease the total amount of air delivered to the room.
- **Example:** The student drafts a professional "Air Balance Report" for a shop project, clearly documenting the CFM readings for every room and justifying any dampers they adjusted to meet the design specifications.

VOG Trait: Work Ready

- **Example:** The student demonstrates mastery of airflow diagnostic tools, such as an **anemometer** or a **flow hood**, to verify that a system is delivering the 400 CFM per ton required for proper dehumidification and cooling.
- **Example:** In their digital portfolio, the student includes a video or photo series of them performing a "Pitot Tube Traverse" to accurately measure the average air velocity in a main trunk line, a high-level skill expected in commercial HVAC work.

Priority Standard 11-6: Work with fuel gases while comprehending industry environmental issues regarding storage and combustion.	
Big Idea(s): 1. **Safe fuel gas handling protects lives and the environment, requiring strict adherence to procedures and storage protocols.**	
Essential Question(s): 1. **What are the possible dangers associated with improper liquefied fuel gas storage? Why is proper and complete combustion of fuel gases so important to human safety and the environment?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
11-6.A Dangers associated with inhaling fuel gasses.	1. **Explain the dangers of Impairment while working.** 2. **Explain how the protective coating on nerves can be damaged.** 3. **Explain that permanent harm can be done to nerves and muscles with prolonged or excessive inhalation.**

	4. **Explain how inhaling gas fumes can have lethal consequences**
11-6.B Uncontrolled combustion of fuel gases	1. **Explain how the right amount of fuel gas can combine with the oxygen in the air and explode with heat or spark.** 2. **Explain how explosions can cause loss of life or cause loss of hearing and/or limbs.** 3. **Explain how severe burns are caused by not following safety precautions when working with fuel gases.** 4. **Explain the financial cost associated with property loss due to explosions.**
11-6.C Incomplete combustion of fuel gases and improper venting.	1. **Explain reason for improper combustion and the formation of high concentrations of carbon monoxide.** 2. **Explain with examples dangers of high levels of carbon monoxide and why this is so important with fuel gases.** 3. **Explain causes of soot.**
11-6.D Fuel gas safety	1. **Detect gas leaks properly and following proper evacuation procedures** 2. **Demonstrate proper venting while working on gas appliances.**

Link to Proficiency Scale

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Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)

• Combustion • Flammability • Limit	• Combustion efficiency • Complete combustion • Glow coil • Excess air • Atmospheric gas burner • Gas burner • Gas manifold • End switch • 100% shutoff • Combination gas valve • Annual fuel utilization efficiency (AFUE) • Combustion air	• Direct-spark ignition (DSI) • Category I furnace • Category II furnace • Category III furnace • Category IV furnace • Electric interlock electromagnetic interference (EMI) • Flame rollout • Hard lockout • Hot-surface igniter • Hot-surface ignition • (HSI) • Direct-venting system • Draft regulator • Drip leg • High-efficiency gas furnace • High-limit switch • Ignition system • Ignition temperature • Flame rectification

Trade Math Crossover:

Fuel Gas Combustion Math (Standard 11-6)

Juniors calculate the precise mixture of oxygen and fuel needed for a safe "Blue Flame".

- **The Rule:** Perfect combustion of **1 cubic foot of Natural Gas** requires **10 cubic feet of air**.
- **The Scenario:** A furnace is rated at 100,000 BTUs. Since 1 cubic foot of gas ~ 1,000 BTUs, this furnace burns 100 cubic feet of gas per hour.
- **The Math:** Calculate the total volume of fresh air required for one hour of operation (100 cu ft gas times 10 cu ft air = 1,000 cu ft of air).

- **The Code Application:** If the mechanical room is only 800 cubic feet, use math to prove why an external "Fresh Air Intake" is legally required

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Samples Gas Problems:

- If 28 inches of water column equal 1psi, then what percentage of one psi is 10 inches of water column?
- Calculating **Combustion Air** requirements (e.g., 50 cu. ft. of air per 1,000 BTU/hr. input).

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 30 Gas Heat and A/C

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Section 41 Gas Fired Heating Systems

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 31 Gas Heat

NFPA 54- 58

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0784 Heating Fundamentals

VOG Portfolio Collection Examples

VOG Trait: A Problem Solver

- **Example:** When a furnace flame appears "lazy and yellow," the student identifies this as a sign of incomplete combustion. They systematically troubleshoot the system; checking for a cracked heat exchanger, a blocked vent, or improper gas manifold pressure; to resolve the safety hazard.

- **Example:** The student calculates the "Combustion Air" requirements for a mechanical room. If the room is "confined," they design a solution using two permanent openings (one high, one low) to ensure the burners have enough fresh air to operate safely and prevent back-drafting.

VOG Trait: Work Ready

- **Example:** The student demonstrates mastery of leak-detection techniques, using both electronic "sniffers" and soap-bubble solutions to verify that every joint in a new gas line is 100% gastight before the system is energized.
- **Example:** In their digital portfolio, the student documents the process of "Clocking the Meter." They use a stopwatch to time the gas meter's revolutions, then use math to verify that the appliance's actual fuel input matches the BTU rating on the nameplate.
- **Example:** Students can take pictures and present how to analyze gas pressure of equipment using electronic manometers.

VOG Trait: An Effective Communicator

- **Example:** The student leads a "Safety Briefing" on the proper storage and transportation of compressed gas cylinders. They clearly explain the "Chain and Cap" rule and why oxygen and fuel gases must be separated by a fire-resistant wall when in long-term storage.
- **Example:** The student can explain the "Carbon Footprint" of different heating fuels to a customer, describing how high-efficiency condensing furnaces reduce greenhouse gas emissions by extracting more heat from the same amount of fuel.

Priority Standard 11-7: Contemporary gas heating appliances.	
Big Idea(s): 1. **Starting up and understanding modern gas heating systems ensures they operate safely, efficiently, and meet customer expectations.**	
Essential Question(s): 1. **What would be good practice in terms of starting, testing and checking systems efficiencies?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
11-7.A Components used in all types of gas furnaces.	**Identify Furnace parts** 1. **Heat Exchanger** 2. **Gas components** 3. **Blower components**
11-7.B Various types of gas heating appliances	1. **Explain the different type of gas appliances** 2. **Describing the basic operation of gas heating appliances**

11-7.C Properties of natural gas and propane.	**1. Compare the characteristics of natural and propane fuel** **2. Identify the safety concerns related to natural and propane fuels**
11-7.D Gas venting and combustion air requirements ● **“B” Vent** ● **PVC**	**1. Identify the ignition and venting methods for various gas appliances.** **2. Measure fuel input and air required for complete combustion**
11-7.E Gas furnace operation	**1. Explain the sequence of operation for 70 to 90% efficient gas furnaces** **2. Explain different categories of furnaces** **3. Explain department of energy standards for new equipment**
11-7.F Ignition systems and pilot proving devices	**1. Describe the operation of ignition and pilot proving devices**
11-7.G Methods of fan control for gas furnaces	**1. Explain methods of fan control for the three categories of gas furnaces**
11-7.H Different gas valves	**1. Identify different types of gas valves**
11-7.I Temperature rise determination	**1. Explain the procedure necessary to obtain proper temperature rise**
11-7.J Gas burners adjustments	**1. Describe the methods of adjusting gas burners**
11-7.K Gas heating systems set-up to the proper manufacture specifications	**1. Adjust gas appliances to manufacture specifications**
11-7.L Safety limits check	**1. Demonstrate the ability to test heating appliance safety systems**
Link to Proficiency Scale	
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Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• 100% shutoff • Atmospheric gas burner • combustion •	• Annual fuel utilization • efficiency • (AFUE) • Combustion efficiency • Complete combustion • Excess air • High-efficiency gas furnace • High-limit switch • Ignition system • Ignition temperature • End switch • Gas burner • Gas manifold • Drip leg • Combustion air • Direct-venting system • Combination gas valve • Draft regulator	• Category I furnace • Category II furnace • Category III furnace • Category IV furnace • Electric interlock electromagnetic interference (EMI) • Direct-spark ignition (DSI) • Flame rollout • Hard lockout • Hot-surface igniter • Hot-surface ignition (HSI) • Glow coil • Flame rectification • Flammability Limit

Trade Math Crossover:

1. AFUE and Energy Savings

The Annual Fuel Utilization Efficiency (AFUE) measures how efficiently a furnace converts fuel to heat. Modern "Contemporary" furnaces are usually 90% to 98% AFUE.

- **The Data:** A homeowner is replacing an old 70% AFUE furnace with a new 96% AFUE model. Their average winter gas bill is $400/month.
- **The Math:** 1. Calculate the "Wasted Dollars" in the old system ($400 \times 0.30 = \$120$ lost up the chimney).

2. Calculate the "Wasted Dollars" in the new system (400 times 0.04 = 16 lost).

- **The ROI:** How much will the homeowner save per 5-month winter season? If the new furnace costs $4,000, how many years will it take for the energy savings to "pay back" the investment?

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2. Condensate Production (Latent Heat of Vaporization)

High-efficiency furnaces produce water (condensate) as a byproduct of combustion. 11th graders must calculate this volume to ensure drainage systems are sized correctly.

- **The Rule of Thumb:** A 90%+ furnace produces approximately **0.8 gallons of water per hour** for every 100,000 BTUs of input.
- **The Scenario:** A 120,000 BTU furnace runs for 10 hours a day during a cold snap.
- **The Math:** Calculate the total gallons of acidic condensate produced in one day (1.2 times 0.8 times 10).
- **The Code Application:** If a condensate neutralizer kit is rated for 500 gallons, how many days of operation can occur before the media inside the kit must be replaced?

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3. Two-Stage Heating Logic (Manifold Pressure)

Contemporary furnaces often have "Two-Stage" gas valves. They run at a lower BTU capacity (Low Fire) for comfort and shift to "High Fire" only when it is extremely cold.

- **The Data:** * High Fire: 3.5" w.c. (water column)
  - Low Fire: 1.7" w.c.
- **The Math:** If a technician measures the manifold pressure and finds it is at **2.5" w.c.**, what percentage of the "High Fire" pressure is the valve currently delivering?
- **The Troubleshooting Challenge:** If the furnace is "Short Cycling" on High Fire, but the manifold pressure is set to 4.0" w.c., calculate the percentage of "Over-firing" based on the 3.5" w.c. specification.

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4. Venting: Total Equivalent Length

Because high-efficiency furnaces use plastic (PVC) pipe, the friction of the pipe limits how far the exhaust can travel.

- **The Data:** A manufacturer allows **60 feet** of 2-inch PVC.

- Every 90° elbow adds **5 feet** of "equivalent length."

- **The Scenario:** A technician plans a 40-foot run with five 90° elbows.
- **The Math:** Calculate the Total Equivalent Length (40 + 5 times 5 = 65 feet).
- **The Engineering Decision:** Does this meet the code? If the limit is 60 feet, the student must use math to determine if switching to 3-inch pipe (which has a 100-foot limit) is the only safe solution.

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5. Combustion Analysis (Excess Air and CO2)

Technicians use digital analyzers to measure the "Health" of the flame.

- **The Ratio:** For Natural Gas, the ideal CO2 range is **8.5% to 9.5%**.
- **The Scenario:** An analyzer shows a CO2 reading of **7.2%** and an Excess Air reading of **60%**.
- **The Math:** 11th-grade students learn that high excess air "dilutes" the CO2. If the goal is 9% CO2, calculate the percentage increase in CO2 needed to reach the target.
- **The Diagnostic:** Does 7.2% CO2 indicate the furnace is "Leaning out" (too much air) or "Rich" (too much fuel)? Use the math to justify adjusting the inducer motor speed or gas pressure.

Sample Venting Problems:

- If a furnace vent cannot exceed 80 feet and each elbow is considered 5 feet, how many elbows are allowed if the horizontal and vertical runs total 40 feet?
- Calculating **Temperature Rise** by subtracting the return air temp from the supply air temp.

<u>Suggested Resources</u>

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 30 Gas Heat and A/C

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Section 41 Gas Fired Heating Systems

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 31 Gas Heat

NFPA 54- 58

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593
Apprenticeship Correlation A0784 Heating Fundamentals
VOG Portfolio Collection Examples **VOG Trait: Work Ready** • **Example:** During a "High-Efficiency System Start-Up," students work in pairs to perform a full commission of a 90% AFUE gas furnace. They measure fuel input, manifold pressure, and temperature rise to verify the unit meets every manufacturer specification • **Example:** Students show examples of furnace vent types, high efficiency vs conventional. **VOG Project:** High-Efficiency System Start-Up: Description: Working in pairs, students perform a full start-up on a 90% efficient gas furnace, measuring fuel input, air combustion, and temperature rise to ensure it meets manufacturer specifications. (VOG Alignment: Work Ready.)

Priority Standard 11-8: Ability to conduct a start-up on gas heating systems.	
Big Idea(s): 1. **Systematic troubleshooting allows technicians to quickly diagnose and fix gas heating problems, minimizing downtime and maximizing safety.**	
Essential Question(s): 1. **How does the initial startup procedure of a heating system ensure both safety and efficiency?** 2. **What role does each component of a heating system (e.g., thermostat, controls, motors) play during the startup process, and how do they work together to achieve optimal performance?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
11-8.A Methods for startups and adjusting gas appliances for proper operation to the manufacturer's specifications and efficiency.	1. **Make proper air / fuel adjustments** 2. **Adjust to obtain CO levels, and stack temperature.** 3. **Adjust safe and efficient combustion** 4. **Check the operation of an induced draft blower by blocking flue outlet** 5. **Explain the procedure necessary to obtain proper temperature difference across a heat exchanger**
11-8.B Functions and applications of regulators.	1. **Check gas valve regulator operation**
11-8.C Operation and the methods of pilot/burner ignition	2. **Check the flame-sensing current of the flame sensing device.**

	3. Test and change a thermocouple flame-sensing device. **4. Test spark modules for proper operation.** **5. Test hot surface ignition modules for proper operation.**
11-8.D Gas heating systems adjustments to the proper manufacture specifications	**1. Explain the information required to start gas appliances to manufacture requirements**
11-8.E Heating appliance testing and safety systems	**1. Perform safety lockout test procedures for gas systems.** **2. Install and testing a fan/limit control to identify the proper set point of the control.**

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• 100% shutoff • Atmospheric gas burner • combustion • Flammability • Limit • Ignition system • Ignition temperature	• Annual fuel utilization efficiency (AFUE) • Combustion efficiency • Complete combustion • Excess air • Gas burner • Gas manifold • Direct-venting system • Draft regulator • Combustion air • Combination gas valve	• Category I furnace • Category II furnace • Category III furnace • Category IV furnace • Electric interlock electromagnetic interference (EMI) • Direct-spark ignition (DSI) • Flame rollout • Hard lockout

	• High-efficiency gas furnace • High-limit switch • End switch • Flame rectification	• Hot-surface igniter • Hot-surface ignition (HSI) • Glow coil • Drip leg

Trade Math Crossover:

Gas System Start-Up: Temperature Rise (Standard 11-8)

Technicians must verify that a furnace is not "Short Cycling" or "Overheating" by calculating the Temperature Rise.

- **The Formula:** Output BTUs = 1.08 CFM times Temperature Rise (Δ T).
- **The Scenario:** A furnace has an output of 80,000 BTUs and a blower moving 1,200 CFM of air.
- **The Math:** 1. Rearrange the formula to find Δ T: Δ T = 80,000 div (1.08 times 1,200).

2. Calculate the expected rise (80,000 div 1,296 = 61.7° F).

- **The Field Test:** If the return air is 70°F and the supply air is 150°F (Δ T = 80° F), the math shows the airflow is too low. What is the actual CFM?

Sample Gas Problems:

- If a furnace supply air reads 130 degrees and the return is 60 degrees what is the temperature rise across the heat exchanger?

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 30 Gas Heat and A/C

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Section 41 Gas Fired Heating Systems

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 31 Gas Heat

NFPA 54

NFPA 58

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Apprenticeship Correlation

A0784 Heating Fundamentals

VOG Portfolio Collection Examples

VOG Trait: An Effective Communicator

- **Example:** In a "Virtual Startup" AI assignment, the student narrates the sequence of operation for a gas furnace—from the inducer motor start to the flame rectification—explaining each safety "interlock" to a simulated junior technician

VOG Trait: A Problem Solver

- **Example:** Students can display pictures of themselves recording temperature reading while checking temp rise across heat exchangers.

Priority Standard 11-9 Systematically troubleshoot and to service a gas system.	
Big Idea(s): 1. **Proper refrigerant handling safeguards technicians and the environment, ensuring compliance with EPA and HVAC industry standards.**	
Essential Question(s): 1. **What are the two major areas to check when trouble shooting a system?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
11-9.A Malfunctioning gas appliance testing	1. **Determining if the problem is electrical or mechanical**
11-9.B Faulty electrical components testing	1. **Using electrical diagrams and test instruments to determine which component is faulty**
11-9.C Faulty mechanical components testing	1. **Using test instruments to determine which component is faulty**
11-9.D Proper Repairs in professional manor	1. **Use proper technique will replace and test faulty component**
Link to Proficiency Scale	

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• 100% shutoff • Combination gas valve • combustion • Draft regulator • Flammability • Limit • Gas burner • Gas manifold	• Annual fuel utilization efficiency (AFUE) • Combustion efficiency • Complete combustion • Flame rollout • Excess air • Atmospheric gas burner • High-efficiency gas furnace • High-limit switch • Ignition system • Ignition temperature • Drip leg • End switch • Flame rectification • Combustion air	• Category I furnace • Category II furnace • Category III furnace • Category IV furnace • Electric interlock electromagnetic interference (EMI) • Hard lockout • Hot-surface igniter • Hot-surface ignition (HSI) • Glow coil • Direct-spark ignition (DSI) • Direct-venting system

Trade Math Crossover:

1. Flame Rectification (The Microamp Signal)

Modern gas furnaces use a "Flame Sensor" to prove a flame exists. It works by "rectifying" AC voltage into a tiny DC current (µA) that flows through the flame.

- **The Data:** A control board requires a minimum of **2.0 µA** to stay energized.
- **The Scenario:** A technician measures the signal and finds it is fluctuating between **1.5 µA** and **1.8 µA**.
- **The Math:** Calculate the "Signal Deficit" percentage (2.0 - 1.5 div 2.0).
- **The Diagnostic:** If the signal is 25% below the threshold, the furnace will "lock out" after 3 seconds. Use this math to explain why a dirty flame sensor (increasing resistance) causes the furnace to shut down.

2. Inducer Motor: Pressure Switch Logic

Before the gas valve opens, an inducer motor must create a vacuum (Negative Pressure) to prove the vent is clear.

- **The Data:** The pressure switch is rated to close at **-0.65" w.c.** (inches of water column).
- **The Scenario:** A technician uses a digital manometer and measures a vacuum of **-0.58" w.c.** * **The Math:** Calculate the difference between the actual vacuum and the "Trip Point" (0.65 - 0.58 = 0.07").
- **The Troubleshooting Deduction:** Since the vacuum is 10% too weak, the switch will not close. Is the problem a failing motor (not spinning fast enough) or a partial blockage in the flue pipe?

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3. Temperature Rise (The Airflow Formula)

If a furnace is "Tripping on High Limit," it means it is getting too hot. This is almost always an airflow issue.

- **The Formula:** CFM = Output BTUs ÷ 1.08 times Temp Rise (Δ T)
- **The Scenario:** A furnace has an output of **80,000 BTUs**. The return air is **70°F** and the supply air is **160°F** (Δ T = 90°F).
- **The Math:** 1. Calculate the current CFM (80,000 ÷ 1.08 times 90).

2. If the manufacturer's data plate says the system needs **1,200 CFM**, calculate the "Airflow Deficiency" (1,200 - 823).

- **The Solution:** Use this math to prove to the customer that their "high-efficiency" air filter is too restrictive and is choking the furnace.

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4. Gas Valve: Manifold Pressure Adjustment

To troubleshoot poor heating or "sooting," you must verify the gas pressure entering the burners.

- **The Data:** A Natural Gas furnace is rated for **3.5" w.c.** on high fire.
- **The Scenario:** You measure **3.1" w.c.** * **The Math:** 1. Calculate the percentage of "Under-firing" ([3.5 - 3.1] ÷ 3.5).

2. Since the heat output is roughly 11% low, the house will take 11% longer to warm up.

- **The Adjustment:** If one full turn of the regulator screw equals 0.2" w.c., how many turns are needed to reach exactly 3.5"?

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5. Hot Surface Igniter (HSI) Resistance

An HSI glows white-hot to light the gas. As they age, their resistance increases until they can no longer get hot enough.

- **The Formula:** $P = V^2 \div R$ (Power in Watts = Voltage squared ÷ Resistance).
- **The Scenario:** A 120V igniter needs at least **400 Watts** of energy to light the gas.
- **The Math:** 1. Calculate the maximum resistance (R) allowed to reach 400 Watts ($120^2 \div 400 = 36$ Ohms).

2. A technician measures the igniter at **55 Ohms**.

- **The Diagnostic:** Calculate the actual wattage (14,400 ÷ 55 = 261 Watts). Explain why 261 Watts is insufficient for ignition and why the igniter must be replaced even though it still "glows."

Sample Step-Down problems

- What is the stepdown ratio of a control transformer that has a primary voltage of 120 and generates a secondary voltage of 24?

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 30 Gas Heat and A/C

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Section 41 Gas Fired Heating Systems

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 31 Gas Heat

NFPA 54- 58

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0784 Heating Fundamentals

VOG Portfolio Collection Examples

VOG Trait: Skilled Socially

- **Example:** The student demonstrates 100% compliance with EPA Section 608 standards during refrigerant recovery. They explain to a peer how preventing even small "de minimis" releases protects the local community from long-term ozone depletion.

VOG Trait: A Critical Thinker

- **Example:** Students can document themselves recording voltage readings on equipment that is not operating correctly.

Priority Standard 11-10: Handle refrigerants while comprehending industry environmental issues regarding them.	
Big Idea(s): 1. **Understand superheat, subcooling, and coil temperature differences helps technicians evaluate system health and cooling efficiency.**	
Essential Question(s): 1. **What are the reasons the 608 Certification to HVAC technicians?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
11-10.A Refrigerants Handling	1. **Exhibited safe refrigerant handling and applications.** 2. **Demonstrated proper system charging by weight and superheat & sub-cooling, PT relationships.** 3. **Describe the methods of determining when a recovery cylinder is full.** 4. **Describe system dependent and self-contained recovery equipment.** 5. **Describing the problems associated with mixing of refrigerants.** 6. **Explaining how to determine empty cylinder weight.** 7. **Calculating 80% full weight of cylinder and refrigerant** 8. **Explaining the problems associated with contaminants such as acid, oil, and old refrigerant left in a refrigerant system after recovery**
11-10.B ASHRAE Refrigerant Safety Classification of Refrigerants for Toxicity and Flammability	1. **Categorize different classes of refrigerants, physical and chemical properties in essay form.**

11-10.C Improper handling or disposal and emission into the atmosphere.	**1. Apply all the Knowledge to pass a written test on safe refrigerant handling and applications.** **2. Explain HCFC, HFC, CFC** **3. Explain effects of Chlorine** **4. Compare effects on Earth Issues Human Health Issues**
11-10.D Proper recycle, recover, reclaim refrigerant to EPA 608 standards at all types 1, 2, and 3	**1. Demonstrate proper system recovery and recharging.** **2. Explain EPA section 608 standards for all types of certifications** **3. Describe difference between recycled and reclaimed refrigerant**
11-10.E Manually pump down a system with liquid line service valves	**1. Demonstrate manual pump down a system.**
11-10.F Isolate system components	**1. Demonstrate how to isolate system components.**
11-10.G EPA certification requirements	**1. Explain EPA 608 certifications** **2. Describe requirements associated with maintaining certifications** **3. List the EPA certification requirement types and levels of servicing**

Link to Proficiency Scale

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- Tier 1: Common, everyday words (Basic communication).
- Tier 2: High-frequency academic words (Used across various subjects/trades).
- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)

• Capture • Chlorine • Global warming • Hazardous waste • Reclaim • Recover • Recycle • Refrigerants	• Ozone depletion potential (ODP) • Global warming potential (GWP) • De minimus • EPA certification • Universal certification • Environmental Protection Agency (EPA) • Clean Air Act (CAA) • Atmospheric balancing • Active recovery • Pump down	• Active recovery • Back seated valve • Front seated valve • CFC • HFC • HCFC • Mid-seated valve • Low-loss fitting • Motor vehicle air conditioning (MVAC) • Passive recovery • Recovery cylinder • Montreal Protocol

Trade Math Crossover:

1. Calculating Annual Leak Rates (The EPA Rule)

The EPA mandates that commercial and industrial refrigeration systems exceeding 50 lbs. of charge must be repaired if they leak above a certain percentage per year.

- **The Formula:**

$$\text{Leak Rate \%} = \frac{\text{Lbs of Refrigerant Added}}{\text{Total System Charge}} \times \frac{365}{\text{Days since last addition}} \times 100$$

- **The Scenario:** A supermarket rack holds **400 lbs.** of R-404A. A technician adds **25 lbs.** to top it off. It has been **120 days** since the last time refrigerant was added.
- **The Math:** 1. Calculate the base ratio: 25 / 400 = 0.0625.

2. Calculate the time factor: 365 / 120 = 3.04.

3. Final Leak Rate: 0.0625 times 3.04 times 100 = 19%.

- **The Regulatory Check:** If the EPA limit for commercial refrigeration is **20%**, is this store legally required to perform a formal leak inspection and repair within 30 days?

2. Recovery Cylinder Safety (The 80% Fill Rule)

To allow for hydrostatic expansion (pressure increases as the tank gets warm), recovery cylinders must never be filled beyond 80% of their volume by weight.

- **The Data:** * **WC (Water Capacity):** 47.7 lbs. (This is the weight of the water the tank could hold).
    - **TW (Tare Weight):** 28 lbs. (The weight of the empty tank).
- **The Math:** 1. Calculate the maximum refrigerant weight: 47.7 times 0.80 = 38.16 lbs.

2. Calculate the **Total Gross Weight** (Tank + Refrigerant) allowed on the scale: 28 + 38.16 = 66.16 lbs.

- **The Field Safety:** If a technician's scale reads **70 lbs.**, explain why the tank is dangerously overfilled and could potentially explode if left in a hot service van.

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3. Recovery Efficiency: Vacuum Levels

The EPA requires recovery machines to pull a specific vacuum level based on the size of the appliance and the high-pressure nature of the refrigerant.

- **The Data:** For a medium-pressure appliance containing more than 200 lbs. of R-22, the technician must pull a vacuum of **10 inches of Mercury (Hg)**.
- **The Math:** If the atmospheric pressure is **29.92" Hg**, and the technician has only pulled down to **25" Hg absolute**, how many more inches of vacuum must be achieved to meet the EPA standard?
- **The Science:** Why is "deep recovery" mathematically necessary to protect the ozone layer? (Hint: Calculate the percentage of gas remaining at 0" Hg vs. 10" Hg vacuum).

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4. Global Warming Potential (GWP) Comparisons

Juniors must understand why the industry is "phasing down" HFCs like R-410A in favor of A2L refrigerants like R-32.

- **The Data:** * **R-410A GWP:** 2,088
    - **R-32 GWP:** 675
- **The Scenario:** A residential system leaks **10 lbs.** of refrigerant into the atmosphere.

- **The Math:** 1. Calculate the "CO2 Equivalent" for the R-410A leak (10 times 2,088 = 20,880 lbs. of CO2).

2. Calculate the "CO2 Equivalent" for the R-32 leak (10 times 675 = 6,750 lbs. of CO2).

- **The Environmental Impact:** How many times more damaging to the climate is the R-410A leak compared to the R-32 leak?

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5. Temperature-Pressure Relationship in Recovery

Before beginning recovery, a technician must verify the refrigerant type using the P/T relationship to ensure the gas isn't contaminated.

- **The Scenario:** A recovery tank labeled **R-134a** is sitting in a shop at **70°F**. A technician connects a gauge and reads **95 PSIG**.
- **The Math:** According to a P/T chart, R-134a at 70°F should have a pressure of **71.1 PSIG**.
- **The Diagnostic:** Calculate the pressure difference (95 - 71.1 = 23.9 PSI).
- **The Decision:** Since the pressure is significantly higher than the saturation point, does the math suggest the tank contains "non-condensable" (air) or the wrong refrigerant? Should the technician recover this into a clean tank or a contaminated tank?

Sample Tare Weight Problems:

- Use tank weight listed on recovery bottles and calculate percentages to ensure they are not over filled.

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 13 Refrigerants
- Chapter 14 zeotropic Blends
- Chapter 15 Refrigerant recovery

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Section 4 Refrigerants

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 9 Refrigerant management

International mechanical Code

OSHA.Gov: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593
Apprenticeship Correlation A0787 EPA Refrigerant Standards
VOG Portfolio Collection Examples. **VOG Trait: A Critical Thinker** • **Example:** Using a Pressure-Enthalpy (P-H) chart, the student plots a system's performance. They use **Superheat** and **Sub-cooling** data to "diagnose" a restricted metering device, proving the system is not low on charge but rather "bottlenecked" **VOG Trait: Skilled Socially** • **Example:** The student demonstrates 100% compliance with EPA Section 608 standards during refrigerant recovery. They explain to a peer how preventing even small "de minimis" releases protects the local community from long-term ozone depletion **VOG Trait: Work Ready** • **Example:** Students can document themselves performing recovery of refrigerants.

Priority Standard 11-11: Refrigeration cycle and superheat, sub-cooling, and coil temperature differences.

Big Idea(s):

1. **HVAC systems work by moving heat using refrigerants in different forms.**
2. **Knowing where the refrigerant is in the cycle and what it's doing helps techs fix and improve systems.**
3. **Understanding superheat, subcooling, and temperature changes shows if a system is working right.**

Essential Question(s):

1. **Why would a technician need to know what the temperature and pressures are throughout the refrigeration system?**

Learning Outcomes

Students will know:	*As evidenced by:*
11-11.A The four major components of the vapor compression refrigeration system.	**1. Label the four major components: refrigeration cycle diagram and refrigerant lines.** **2. List the components that separate the high side from the low side of the system.** **3. Draw a refrigeration cycle on a pressure-enthalpy chart**
11-11.B Types of evaporators and their uses in the refrigeration and air conditioning field.	**1. Explain that the evaporator absorbs heat from what is being cooled.** **2. Identify evaporator types** **3. Check and adjusting superheat to manufacturers' specifications where appropriate** **4. Explain measuring temperature difference between fluid entering the evaporator and leaving**

	5. Determine the Mean Effective Temperature Difference (METD) for evaporators **6. Calculate superheat om all evaporators**
11-11.C Types of condensers and uses in the refrigeration and air conditioning field.	**1. Explain that the condenser removes heat, absorbed in the evaporator and compressor.** **2. Identify air cooled condensers,** **3. Identify water cooled condensers.** **4. Determine proper air and water flow.** **5. Explain drawing air through coils** **6. Explain opposing flow water verse refrigerant** **7. Check and adjust sub-cooling to manufacturers' specifications** **8. Validate the correct performance of a condenser** **9. Calculate Sub-Cooling on all Condensers**
11-11.D State & condition of refrigerant in the system; Liquid, Vapor, Sub-cooled liquid, Superheated Vapor	**1. Explain the changes that the refrigerant goes through as it travels through the system moving heat**

Link to Proficiency Scale

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- Tier 2: High-frequency academic words (Used across various subjects/trades).
- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)

• compressor	• High-pressure side	• Accumulator
• condenser	• Hot Gas discharge line	• Crankcase heater
• conduction	• Liquid line	• Cooling tower
• convection	• Low-pressure side	• Filter drier
• Condensation	• Pressure drop	• Flash gas
• Evaporation	• Reciprocating	• Off cycle
	• Refrigerant	• On cycle
	• Subcooled	• Liquid receiver
	• Suction line	• Series connection
	• Superheat	• Temperature difference (td)
	• evaporator	• Thermostatic expansion valve
		• Metering device
		• Basic refrigeration cycle

Trade Math Crossover:

Advanced Refrigeration: Subcooling & Glide (Standard 11-11)

Juniors move beyond simple charging to calculating **Mean Effective Temperature Difference (METD)** and handling blended refrigerants with "Glide".

- **The Scenario:** You are charging a system with **R-407C** (a blended refrigerant). At 80 PSI, the "Bubble Point" (liquid) is 20°F and the "Dew Point" (vapor) is 32°F.
- **The Math:** 1. Calculate the **Total Glide** (32 - 20 = 12° F).

2. If the actual pipe temperature is 45°F, calculate the **Superheat** using the Dew Point (45 - 32 = 13° F} superheat).

- **The Comparison:** Show how much the technician would be "off" if they accidentally used the Bubble Point instead of the Dew Point for this calculation.

Sample Subcooling Problems:

- If your liquid line temp reads 90 and your saturation refrigerant temp reads 102 what is the amount of sub cooling?
- Calculating **Superheat and Subcooling** to verify precision refrigerant charging.

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 16 System evacuation
- Chapter 19 Trouble Shooting

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 20 metering devices

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 24 Expansion Devices

OSHA.Gov:

Apprenticeship Correlation

A0787 EPA Refrigerant Standards

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** A student uses a **Pressure-Enthalpy (P-H) Chart** to plot a system's current operating state. They can explain how a change in outdoor ambient temperature shifts the "high side" of the curve and how the system compensates to maintain the required heat rejection.
- **Example:** The student differentiates between "Sensible Heat" (changing temperature) and "Latent Heat" (changing state). They justify why the evaporator coil must stay below the "Dew Point" of the return air to ensure proper dehumidification of the space.

VOG Trait: A Problem Solver

- **Example:** When troubleshooting an AC unit that isn't cooling, the student measures **Superheat** and **Sub-cooling**. If they find high superheat and high sub-cooling, they correctly diagnose a "restricted metering device" (like a clogged TXV) rather than simply adding more refrigerant, which would overcharge the system.

- **Example:** The student calculates the "Delta-T" (temperature difference) across the evaporator coil. If the difference is too high (e.g., 26°F instead of the standard 18-22°F), they identify low airflow as the root cause and inspect the air filter and blower motor.

VOG Trait: An Effective Communicator

- **Example:** The student narrates a technical "Service Report" for a mock customer, clearly explaining why a "Sub-cooling" measurement is the only accurate way to verify the charge on a system with a Thermostatic Expansion Valve (TXV).
- **Example:** In a peer-to-peer lab, the student uses a **P/T Chart** to explain "Saturation" to a classmate, illustrating how the refrigerant exists as both a liquid and a vapor simultaneously inside the condenser and evaporator coils.

VOG Trait: Work Ready

- **Example:** The student demonstrates the professional habit of "Digital Verification." They use a Bluetooth-enabled manifold gauge set to sync live data to a mobile app, creating a digital "birth certificate" for the system that logs superheat, sub-cooling, and target values for future service calls.
- **Example:** The student accurately identifies the "critical charge" on a micro-channel coil system, recognizing that even a few ounces of refrigerant over or under the nameplate weight can drastically affect the **Coil Temperature Difference (TD)** and system longevity.
- **Example:** Students can document themselves performing superheat and subcooling calculations.

Priority Standard 11-12: Inside and outside production and the possibility of Work based Learning (WBL)	
Big Idea(s): 1. **Good workers show up on time, communicate well, and act professionally.** 2. **WBL helps students practice real job skills and learn what employers expect.** 3. **Getting ready for interviews and the workplace helps students succeed in their careers.**	
Essential Question(s): 1. **What are marketable skills?** 2. **How can you benefit from WBL?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
11-12.A Expectations of all parties involved in work based learning.	1. **Define expectations of each partner.** 2. **Refer to the Work Study Guidelines for roles and expectations.** 3. **Come to work every day on time.** 4. **Will to take direction.** 5. **Motivate to accomplish the task at hand.**
11-12.B Factors that would affect the student contribution in the workplace	1. **Formulate a list of what they can bring into the workplace and how each item may impact their job. School subjects; past experiences; self-concept and personality; needs, values and interests; knowledge skills and attitudes; career Priority Standards and plans.** 2. **Demonstrate and contribute to the success of a team.** 3. **Doing a self-assessment of skills using the above list as a guide. Explain how these skills would be valuable to the industry.** 4. **Read and interpret workplace documents.** 5. **Demonstrate ability to respond in writing clearly and concisely.**
11-12.C Develop an awareness of building effective communication in the workplace.	1. **Discuss verbal and non-verbal communication. List ways negative**

	nonverbal communication may be displayed. 2. Role play ways of demonstrating effective verbal communication. 3. Contribute new ideas. 4. Work with initiatives and co-workers.
11-12.D Create a student guide in preparation for an interview.	1. Outline and describe the three stages of an interview –greeting, exchange and parting. 2. Students will role play the stages of the interview.
11-12.E Post interview procedures	1. Follow-up activity after completion of the interview. 2. Review interviews.
11-12. Develop a readiness guide for the worksite.	1. Discuss work site items: transportation; hours of work; absence and tardiness; conflict resolution; role of student, teacher, and workplace supervisor; dress code; job description; expectations

[Link to Proficiency Scale]

Math Trade Crossover

Production & Work-Based Learning (Standard 11-12)

Students at this level often enter the workforce, requiring math for "Job Costing" and "Estimating".

- **The Scenario:** You are tasked with installing 150 feet of copper refrigerant line. The copper costs $4.50/ft, and the labor is estimated at 30 minutes per 10-foot section.
- **The Math:** 1. Calculate Material Cost (150 times 4.50 = $675).

2. Calculate Total Labor Hours ($150 ÷ 10 = 15 sections; 15 times 30 mins = 450 mins or 7.5 hours).

3. If the shop bills at $110/hr., calculate the total "Labor Bid" (7.5 times 110 = $825).

- **The Final Estimate:** What is the total price of the job including a 20% "Profit and Overhead" markup?

Sample Estimating Problems:

- Estimating labor hours and material costs for "Change Orders" in a professional simulation.

VOG Portfolio Collection Examples

VOG Trait: Work Ready

- **Example:** The student finalizes their **Digital Portfolio**, including high-resolution photos of their gas piping and electrical wiring labs. They use their **Student Competency Checklist** to prove to a potential employer that they have mastered the intermediate skills required for a field internship.

VOG Trait: Skilled Socially

- **Example:** While working on a "Live Work" project in the school, the student coordinates with the plumbing and electrical shops to ensure the HVAC unit's condensate lines and power supplies are installed without interfering with other trades' work.

HVAC

Grade 12

Priority Standard 12-1: Comprehend industry environmental issues regarding storage and combustion.	
Big Idea(s) 1. **Working safely with fuel oil and understanding its environmental impact ensures responsible energy use and protects communities and ecosystems.**	
Essential Question(s) 1. **What are the possible dangers associated with improper oil storage?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
12-1.1 Dangers associated with fuel oil fumes and leaks	1. **Explain how leaking oil is toxic to animals and plants** 2. **Explain dangers of short-Term Exposure to fumes from heating oil** 3. **Explain long-Term Exposure to heating oil fumes.**
12-1.2 Environmental concerns with fuel oil combustion gases.	1. **Explain with examples dangers of elevated levels of carbon monoxide** 2. **Explain causes of soot and dangers of unburned carbon, unburned oil**
12-1.3 Fuel oil safety	1. **Protect skin from contact with oil** 2. **Demonstrate proper venting while working on burners**
Link to Proficiency Scale	
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Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Combustion • Boiler • Furnace • Water heater • Chimney • Carbon • Oil filter • Fuel oil • vaporized • Gap	• atomizing • Oil furnace • Oil pump • orifice • Vent alarm • Supply line • Return oil line • Vent pipe • Fill pipe • Direct vent • Viscosity	• Gun-type burner • Bleed port • Pressure tap plug • Two-stage oil pump • Single-stage oil pump • Solid-state igniter • Intermittent ignition • Interrupted ignition • Above ground tank • Underground tank • Primary control • Spray angle • Stack control • Transient light • Burner fan • Cad cell • Draft control • Electrodes • Flexible coupling • Ignition transformer • Isolation relay • Air band

Trade Math Crossover:

1. Thermal Expansion of Stored Fluids

Refrigerants and fuel oils are stored in closed containers. As the ambient temperature rises, the liquid expands. If there is no "ullage" (vapor space), the pressure will rise infinitely until the container ruptures.

- **The Formula:** $\Delta V = V_0$ times β times ΔT
    - (β for Refrigerant 410A is approximately 0.0016 per °F)
- **The Scenario:** A recovery cylinder is filled with **40 lbs.** of liquid refrigerant (approx. 4 gallons) at 60°F in the morning. By 3:00 PM, the service van reaches 130°F.

- **The Math:** 1. Calculate the change in temperature (Δ T = 130 - 60).

2. Calculate the change in volume (Δ V = 4 times 0.0016 times 70).

- **The Environmental Risk:** If the tank was filled to 98% capacity, calculate if the 0.448-gallon expansion will exceed the 2% remaining vapor space. Why is this a major environmental "venting" risk?

2. Stoichiometric Air-Fuel Ratio & CO2 Production

To minimize environmental pollutants (CO and NOx), combustion must be "Stoichiometric"—the perfect ratio where all fuel and all oxygen are consumed.

- **The Data:** Burning **1 cubic foot of Methane (CH_4)** ideally produces **1 cubic foot of CO_2** and requires **2 cubic feet of O_2** (which is found in about 10 cubic feet of air).
- **The Scenario:** A high-efficiency boiler burns **2,500 cubic feet** of natural gas per day.
- **The Math:** 1. Calculate the total volume of CO_2 released into the atmosphere daily.

2. If the burner is out of adjustment and has **50% Excess Air**, calculate the total volume of "flue gas" moving through the chimney.

- **Environmental Impact:** Use the math to explain why "Excess Air" lowers efficiency and increases the carbon footprint by making the blower motor work harder.

3. Net Stack Temperature and Efficiency

The "Net Stack Temperature" is the difference between the flue gas and the room air. Higher stack temperatures mean more heat is being wasted into the environment rather than heating the building.

- **The Formula:** Combustion Efficiency % = 100 - Dry Flue Gas Loss + Latent Heat Loss)
- **The Scenario:** * Boiler A: Stack Temp = $350° F, Room Temp = 70° F (Net = 280° F).
    - Boiler B: Stack Temp = 120° F, Room Temp = 70° $ (Net = 50° F).
- **The Math:** Using a simplified loss of 1% efficiency for every 40° F of Net Stack Temp above 50°F:
    1. Calculate the efficiency loss for Boiler A.
    2. If the building requires **100,000,000 BTUs** per winter, calculate how many extra BTUs Boiler A must burn compared to Boiler B to meet the load.

4. Fuel Storage: Tank Leaks and Soil Contamination

Seniors must understand the environmental liability of oil storage.

- **The Scenario:** A 275-gallon No. 2 fuel oil tank has a "pinhole" leak that drips **1 drop per second**.
- **The Data:** * 15,000 drops ~ 1 quart.
    - 4 quarts} = 1 gallon.
- **The Math:** 1. Calculate drops per hour (60 times 60) and drops per day (3,600 times 24).

2. Calculate how many gallons of oil leak into the soil in a **30-day month**.

- **The Environmental Cost:** If the EPA fine is **10,000 per gallon** of uncontained spill, calculate the potential legal liability for the homeowner after one month.

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5. Refrigerant GWP (Global Warming Potential) Weighting

When decommissioning a 12th-grade "Senior Project" system, students must report the environmental impact of the refrigerant recovered.

- **The Data:** * Refrigerant R-22 GWP = 1,810
    - Refrigerant R-410A GWP = 2,088
- **The Math:** 1. You recover **15 lbs.** of R-22 and **12 lbs.** of R-410A.

2. Calculate the "Equivalent Tons of CO_2" for each (Lbs. times GWP ÷2,000).

- **The Comparison:** Which recovery operation had a greater positive impact on the environment? By how many equivalent tons?

Sample Oil Burner Problems:

- If one gallon of oil produces 140,000 BTUs what size burner nozzle is needed for a house with a calculated heat loss of 100,000 BTUs?

<u>Suggested Resources</u>

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 31 Oil Heat w/ A/C

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545 • Chapter 42 Oil Fired Heat Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5 • Unit 32 Oil Heat **Beckett Training** **Carlin Training** **OSHA.Gov:**
Apprenticeship Correlation A0791 Oil Burner Controls & Servicing
VOG Portfolio Collection Examples **VOG Trait: An Effective Communicator** • **Example:** A student leads a "Safety Stand-Down" for the shop, presenting a case study on the dangers of arc flash. They clearly communicate the required PPE (Category 2 or higher) and the "Boundary" rules for working on live 3-phase commercial panels. **VOG Trait: Work Ready** • **Example:** The student acts as the "Safety Officer" during a rooftop unit (RTU) lift, ensuring all crane signals are standardized and that the "Fall Protection" plan is strictly followed by every member of the team. • **Example:** Students can present images of themselves wearing proper PPE while working with oil.

Priority Standard 12-2: Contemporary oil heating appliances.	
Big Idea(s): 1. **Becoming familiar with modern oil heating systems prepares technicians to install and maintain efficient, reliable heating solutions.**	
Essential Question(s): 1. **How do modern heating appliances integrate technology to enhance energy efficiency, and what impact does this have on both cost and environmental sustainability?**	
Students will know:	*As evidenced by:*
12-2.A Components used in all types of oil systems.	1. **Identify oil systems parts**
12-2.B Types of oil heating appliances • **Furnaces, Boiler, Water heaters**	1. **Explain the different type of oil appliances** 2. **Describe the basic operation of oil heating appliances**
12-2.C The properties of fuel oil #1, #2, #6	1. **Compare the characteristics of fuel oil** 2. **Identify the safety concerns related to fuel oil**
12-2.D Characteristics of fuel oil • **Flash point** • **Fire point** • **Viscosity** • **Carbon Residue** • **Water and sediment** • **Pour point** • **Ash content** • **Distillation quality**	1. **Explain characteristics of fuel oil**
12-2.E Fuel oil storage • **One pipe**	**Describe oil tank installation and piping:** 1. **One pipe**

• Two pipe **• Transfer pump to secondary storage**	**2. Two pipe** **3. Transfer pump to secondary storage**
12-2.F Operation of an oil delay valve Single limits	**1. Operation of an oil delay valve**
12-2.G Oil system limit controls uses **• Single limits** **• Triple aqua stats** **• Fan/limits**	**Testing limit controls** **1. Single limits** **2. Triple aqua stats** **3. Fan/limits**

Link to Proficiency Scale

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Tier 1 (Everyday)	**Tier 2 (Academic)**	**Tier 3 (Technical/Trade)**
• Boiler • Combustion • Furnace • Water heater • Chimney • Carbon • Fuel oil • vaporized • Gap • Oil furnace • Electrodes • Oil pump	• Viscosity • atomizing • Burner fan • Flexible coupling • orifice • Primary control • Spray angle • Stack control • Transient light	• Air band • Cad cell • Draft control • Isolation relay • • Gun-type burner • Bleed port • Pressure tap plug • Two-stage oil pump • Single-stage oil pump • Solid-state igniter • Intermittent ignition • Interrupted ignition • Direct vent • Above ground tank • Underground tank

		• Supply line • Return oil line • Vent alarm • Vent pipe • Fill pipe • Oil filter • Ignition transformer

Trade Math Crossover:

1. Nozzle Flow Rate and Net BTU Output

Oil nozzles are rated in Gallons Per Hour (GPH) at a standard pressure of 100 PSI. However, modern burners often operate at 140 PSI or higher to improve atomization.

- **The Formula:** GPH_{actual} = GPH_{rated} times sqrt P_{actual}÷100
- **The Scenario:** A contemporary burner uses a **0.75 GPH** rated nozzle, but the manufacturer's instructions call for a pump pressure of **150 PSI**.
- **The Math:** 1. Calculate the actual flow rate 0.75 times sqrt 1.5).

  2. If No. 2 fuel oil contains **140,000 BTUs per gallon**, calculate the Total BTU Input.

  3. If the appliance is 87% efficient, calculate the **Net BTU Output** delivered to the home.

2. Combustion Air and Excess Oxygen

Contemporary oil burners use "flame retention" heads to mix air and oil more violently. This allows the burner to run with less "Excess Air," which increases efficiency.

- **The Data:** To burn 1 gallon of oil perfectly (stoichiometric), you need approximately **1,440 cubic feet of air**.
- **The Scenario:** A technician performs a combustion test and finds the burner is running with **25% Excess Air**.
- **The Math:** 1. Calculate the total volume of air being pulled into the heat exchanger for every gallon of oil burned (1,440 times 1.25).

  2. If the room is 1,200 cubic feet, calculate how many times the burner "exchanges" the entire room's air for every gallon of fuel consumed.

3. Pump Cut-Off and Vacuum Leak Detection

Modern oil systems often use a two-stage pump or a "Tiger Loop" de-aerator. High vacuum readings indicate a restriction or an undersized suction line.

- **The Rule:** A single-stage pump should not exceed **6" Hg (inches of Mercury)** of vacuum. A two-stage pump can handle up to **12" Hg**.
- **The Scenario:** An oil tank is 50 feet away and 4 feet below the burner. The 3/8" copper line has a friction loss of **1" Hg per 10 feet** of horizontal run and **1" Hg for every 1 foot** of vertical lift.
- **The Math:** 1. Calculate the horizontal friction loss (50 ÷ 10).

  2. Calculate the vertical lift loss (4 times 1).

  3. Calculate the **Total Calculated Vacuum**.

- **The Diagnostic:** If the gauge reads **15" Hg**, what does the math tell you about the condition of the oil filter or the fuel line?

4. Cad Cell Resistance and Flame Safety

The Cadmium Sulfide (Cad Cell) is the "eye" of the modern oil primary control. It changes resistance based on light intensity.

- **The Data:** * Darkness (No Flame) = >100,000 Ohms
  - Strong Flame = <1,600 Ohms (Ideal is 300–600 Ohms)
- **The Formula:** V = I times R (Used by the controller to sense voltage drop).
- **The Scenario:** The control circuit sends a 24V signal through the Cad Cell.
- **The Math:** 1. If the Cad Cell is dirty and measures **3,000 Ohms**, calculate the current (I) in milliamps.

  2. If the "Safety Lockout" triggers when current drops below **15 mA** (0.015 A), calculate the maximum resistance the Cad Cell can have before the burner shuts down (24 ÷ 0.015).

5. Net Stack Temperature and Efficiency Calculations

High-efficiency oil furnaces must manage "Stack Temperature" to prevent the chimney from rotting while still extracting maximum heat.

- **The Scenario:** * **Old Tech:** Stack Temp = 600° F, Overfire Draft = -0.02" w.c.
  - **Modern Tech:** Stack Temp = 350° F, Overfire Draft = +0.05" w.c. (Positive pressure)

- **The Math:** 1. Calculate the **Temperature Difference** (Δ T) between the old and new systems.

  2. For every 50° F drop in stack temperature, efficiency increases by roughly **1%**. Calculate the estimated efficiency gain of the modern unit.

- **The Engineering Question:** Why does the modern unit require a "sealed" or "positive pressure" venting system while the old unit used a standard chimney? (Hint: Use the relationship between lower temperatures and natural draft).

Sample Oil Tank Problems:

- If the maximum allowable indoor gallon of oil is 660 gallons, what are possible tank combinations a customer could have in their house?
- Calculating line current for 3-phase motors using the square root of 3 (1.732).

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 31 Oil Heat w/ A/C

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 42 Oil Fired Heat

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 32 Oil Heat

Beckett Training

Carlin Training

OSHA.Gov:

Apprenticeship Correlation

A0791 Oil Burner Controls & Servicing

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** The student performs a "submittal review," verifying that the delivered equipment matches the specific electrical and performance requirements listed in the blueprint's "Equipment Schedule."

VOG Trait: Work Ready

- **Example:** Using a set of multi-trade commercial prints, the student identifies a "clash" between a 20" return duct and a fire sprinkler main. They collaborate with the plumbing shop to propose a reroute that satisfies both the International Mechanical Code (IMC) and Fire Code.
- **Example:** A student could present a project outlining the several types of fuel tanks installed in the trade.

Priority Standard 12-3: Ability to conduct a start-up on oil heating systems.	
Big Idea(s): 1. **Proper start-up procedures are vital for verifying safe and effective operation of oil heating systems in residential and commercial applications.**	
Essential Question(s): 1. **When performing an efficiency test, what four individual procedures are required and how are they done?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
12-3.A Startup and adjusting oil burners for proper operation to the manufacturer's specifications and efficiency	1. **Demonstrate how to adjust oil burners per manufacturers' instructions.**
12-3. B Safe start-up of oil-fired equipment ● **Choosing nozzle** ● **Bleeding fuel unit** ● **Adjust nozzle pressure** ● **Adjust combustion air coarse and fine** ● **Set electrodes** ● **Blower speeds** ● **Combustion efficiency**	1. **Demonstrate a warm air start-up and make a proper fan speed selection Belt or Direct drive** 2. **Demonstrate testing an oil-fired burner Analyzing and adjusting, smoke level, net stack temperature, over-fire draft, and CO2 level to obtain safe combustion.** 3. **Service an oil-fired burner with checking the following:** 4. **Electrode settings** 5. **Flame retention head** 6. **Cad cell eye** 7. **Oil pump screen** 8. **Oil filter** 9. **Fuel nozzle**
12-3.C Order of operation of an oil-fired burner primary cad cell safety control circuit.	1. **Measure resistances of a cad cell under different lighting circumstances.**

	2. Perform safety lockout procedures for oil burners
12-3.D Methods of checking safety limits	**1. Demonstrate the ability to test heating appliance safety systems**
12-3.E Fuel oil combustion	**1. Explain fuel to air adjustment**
12-3.F Oil heating systems adjustment to the proper manufacture specifications	**1. Adjust oil appliances to manufacture specifications**
12-3.G Temperature rise	**1. Explain the procedure necessary to obtain proper temperature rise**

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		• Vent pipe • Fill pipe • Above ground tank • Underground tank • Primary control • Spray angle • Stack control • Flexible coupling • Ignition transformer • Isolation relay

Trade Math Crossover:

EXAMPLES:

1. Pump Pressure and Nozzle Output

Most modern oil burners (like Beckett or Carlin) are shipped with a factory pump pressure of 100 PSI. However, to meet the AFUE rating on the nameplate, you often must increase the pressure.

- **The Rule:** If you increase pressure, the flow rate increases.
- **The Formula**: $GPH_{New}=GPH_{Rated}\times 100PNew$
- **The Scenario:** The furnace nameplate requires an input of 0.85 GPH. You have a 0.75 GPH nozzle installed.
- **The Math:** 1. Calculate the required pressure (P) to make a 0.75 nozzle behave like a 0.85.

  2. Calculation: $(0.750 \div .85)^2 \times 100=?$
- **The Result:** You must set the pump to 128 PSI.

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2. The 10-Minute Smoke Test

During start-up, a technician uses a manual pump to pull a sample of flue gas through a filter paper.

- **The Scale:** 0 (White/Clean) to 10 (Black/Soot).
- **The Math:** A "Trace" of smoke (Scale 1) is acceptable during the first 60 seconds. However, for a high-efficiency unit, the "Steady State" smoke must be 0.

- **The Adjustment:** If the smoke test shows a 4, the mixture is "Rich" (too much fuel/too little air). If you cannot increase the air shutter any further, use math to determine if you should decrease the pump pressure by 10% or swap to a smaller nozzle.

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3. Net Stack Temperature and Condensation Risk

If the stack temperature is too high, you are wasting money. If it is too low, the water vapor in the oil exhaust will turn into sulfuric acid and eat the chimney.

- **The Data:** * Ambient (Room) Temp: 68°F
  - Gross Stack Temp: 410°F
- **The Math:** 1. Calculate the **Net Stack Temperature** (410−68=342°F).

  2. **The Safety Range:** For a non-condensing masonry chimney, the Net Stack should be between **300°F and 500°F.**
- **The Diagnostic:** If the Net Stack is 250°F, calculate the percentage of heat you need to "lose" back into the chimney to prevent condensation (300−250=50°F increase needed).

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4. Draft Measurement (Over-Fire vs. Breech)

A "Quality Start-up" requires measuring the "Draft" (vacuum) created by the chimney.

- **The Scenario:** * Draft at the Breech (Chimney pipe): **-0.04" w.c.**
  - Draft Over-Fire (Inside the chamber): -**0.02" w.c.**
- **The Math:** 1. Calculate the "Pressure Drop" through the heat exchanger (0.04−0.02).

  2. **The Rule:** The breech draft should always be roughly **0.02"** stronger than the over-fire draft.
- **The Troubleshooting:** If the over-fire draft is **+0.01"** (Positive Pressure), use the math to prove the heat exchanger is restricted with soot and needs cleaning before the start-up can continue.

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5. Calculating Combustion Efficiency (The Final Grade)

The final step of a 12th-grade start-up is proving the unit meets its AFUE rating.

- **The Formula (Simplified):** ***Efficiency%=***100 − (***Dry Gas Loss + Latent Heat Loss)***
- **The Scenario:** Your analyzer shows:

- CO2: **11.5%**
- Net Stack: **350°F**

- **The Math:** Using a standard oil efficiency chart, 11.5% CO_2 at 350°F Net Stack equals **84.5% Efficiency.**
- **The Comparison:** If the furnace nameplate says **86% AFUE**, the student must adjust the "Air-to-Fuel" ratio. Would closing the air shutter slightly to increase CO2 to **12.5%** get the efficiency closer to the 86% goal? Use the chart to verify.

Sample GPM & Fresh Air Math Examples:

- Follow code requirements to determine fresh air for complete combustion of fuels or ventilation requirements for enclosed spaces.
- Calculating GPM and Pump Head to ensure proper flow through a chiller barrel or cooling tower.

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 31 Oil Heat w/ A/C

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 42 Oil Fired Heat

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 32 Oil Heat

Beckett Training

Carlin Training

OSHA.Gov:

Apprenticeship Correlation

A0791 Oil Burner Controls & Servicing

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** During an oil burner start-up, the student evaluates the "Smoke Spot" test results. If the scale shows a #2 spot, the student analyzes the air-to-fuel ratio and determines whether to increase the pump pressure or adjust the head assembly to achieve a "trace" or #0 spot for maximum efficiency.
- **Example:** The student differentiates between the "Static Pressure" of the burner fan and the "Over-fire Draft." They justify why a positive pressure in the combustion chamber (on a forced-draft unit) requires a different sealing technique than a traditional atmospheric draft unit.

VOG Trait: A Problem Solver

- **Example:** When a burner fails to establish a flame, the student uses a multimeter to test the **CAD Cell** (flame sensor). They determine if the sensor is "seeing" the light or if the resistance is too high, identifying whether the issue is a dirty nozzle, a misaligned electrode, or a faulty primary control.
- **Example:** The student identifies a "pulsating" flame during start-up. They solve the problem by checking the oil suction line for "basing" (air bubbles) and perform a vacuum test on the fuel pump to ensure the underground tank lines are airtight.
- **Example:** Student could document themselves performing a combustion test on an oil-fired system

VOG Trait: An Effective Communicator

- **Example:** The student completes a professional Oil Burner Service Report, documenting the Pump Pressure (PSI), Net Stack Temperature, CO2 percentage, and Draft readings. They explain these technical findings to the customer, highlighting how these numbers prove the system is running safely and efficiently.

VOG Trait: Work Ready

- **Example:** The student demonstrates mastery of the "Bleeding" process for a two-pipe oil system, ensuring all air is purged from the lines to prevent "lockout" calls. They follow the manufacturer’s specific nozzle-matching charts (GPH, Angle, and Spray Pattern) to ensure the flame fits the combustion chamber perfectly.

- **Example:** In their Digital Portfolio, the student includes a video of them performing a "safety lockout" test, proving they can verify that the primary control will shut down the fuel flow within 15–45 seconds if ignition fails, a critical fire-safety requirement.

Priority Standard 12-4: Systematically troubleshoot and service an oil system.

Big Idea(s):

1. **Effective troubleshooting of oil systems requires critical thinking, technical skills, and adherence to safety protocols to ensure peak system performance.**

Essential Question(s):

1. **What three areas would we investigate when trying to determine the cause for a malfunctioning oil burner?**
2. **How do we test ignition and safety controls for operation?**

Learning Outcomes

Students will know:	*As evidenced by:*
12-4.A Oil primary control	**1. Demonstrate testing oil primary control**
12-4.B Ignition transformer	**1. Demonstrate testing Ignition transformer**
12-4.C Fuel unit pressures • **Nozzle** • **Vacuum**	**Demonstrate testing of fuel unit pressures** **1. Nozzle** **2. Vacuum**
12-4.D Limit controls • **Single limits** • **Triple aqua stats** • **Fan/limits**	**Explain testing limit controls** **1. Single limits** **2. Triple aqua stats** **3. Fan/limits**
12-4.E Clogged oil line Maintenance	**Explain how to clear a clogged oil line**
12-4.F Oil filter Maintenance	**Explain how to change oil filter**

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CTECS HVAC

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Trade Math Crossover:

1. The "Safety Lockout" Timer (Timing the Control)

Modern primary controls (like the Honeywell Protectorelay) have a specific "Trial for Ignition" time, usually 15, 30, or 45 seconds.

- **The Scenario:** A burner is locking out. You reset it and use a stopwatch. The flame lights, but the burner shuts down exactly **15 seconds** later.

- **The Math:** If the control is a **15-second lockout** model, the math proves the control "timed out" because it never "saw" the flame.
- **The Diagnostic:** This points specifically to the **Cad Cell** circuit. If the flame was present but the control stopped, calculate the resistance (R) of the Cad Cell. If R > 1,600 **Ω** while the flame is active, the cell is dirty or misaligned.

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2. Nozzle "Drooping" and Heat Exchanger Efficiency

As nozzles wear out, the orifice becomes larger, increasing the flow rate and changing the spray angle. This causes "impingement" (flame hitting the metal), which creates soot.

- **The Data:** A nozzle is rated at **0.85 GPH**. After 3 years without service, it has worn down and is now flowing at **0.92 GPH**.
- **The Math:** 1. Calculate the percentage increase in fuel flow ([0.92 - 0.85] ÷ 0.85).

2. If the furnace was designed for **119,000 BTUs** (0.85 times 140,000), calculate the new BTU input (0.92 times 140,000).

- **The Troubleshooting Deduction:** The system is now **8.2% over-fired**. This extra heat will trip the "High Limit" switch. Use this math to explain to a customer why a $15 nozzle can cause a $5,000 heat exchanger to crack.

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3. Combustion Air: The CO2 vs. O2 Relationship

When troubleshooting "smoky" starts or rumbling, a technician must balance the air-to-fuel ratio using an analyzer.

- **The Rule:** In oil combustion, CO_2 and O_2 have an inverse mathematical relationship. For every **1% drop in O_2**, CO_2 should rise by approximately **0.7%**.
- **The Scenario:** Your analyzer shows **6% \$$O_2$** and **9% CO_2**.
- **The Math:** 1. Perfect oil combustion is roughly **15.4% CO_2** at **0% O_2**.

2. Calculate the "Expected CO_2" for your O_2 reading: 15.4 - (6 times 0.7) = 11.2%.

- **The Diagnostic:** Since your actual CO_2 (9%) is much lower than the expected CO_2 (11.2%), the math proves there is **"Unmeasured Air"** entering the system (likely a leak in the heat exchanger or a loose clean-out door).

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4. Fuel Pump Vacuum: Troubleshooting Restrictions

If an oil burner is "pulsating," it often means the pump is struggling to pull oil from the tank.

- **The Formula:** Total Vacuum = Vertical Lift (1" per foot)} + Line Friction (1" per 10ft of 3/8" tubing).
- **The Scenario:** A tank is 40 feet away and 5 feet below the pump.
- **The Math:** 1. Vertical Lift: 5 inches Hg.

2. Line Friction: 40 ÷ 10 = 4 inches Hg.

3. **Calculated Total:** 9 inches Hg.

- **The Troubleshooting:** If your vacuum gauge reads **18 inches Hg**, the math proves there is a physical restriction. Use this to isolate the problem: is it a plugged filter, a kinked line, or a stuck "Check Valve"?

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5. Electric Ignition: Transformer Voltage Drop

Old-style "Iron Core" transformers can weaken over time, leading to delayed ignition (the "Boom" on start-up).

- **The Data:** A 120V primary ignition transformer should output **10,000V** at the electrodes.
- **The Ratio:** 120:10,000 = 1:83.3.
- **The Scenario:** You measure the house voltage and find it is only **108V** because of a heavy load on the circuit.
- **The Math:** Calculate the actual spark voltage (108 times 83.3).
- **The Conclusion:** The spark is now only **8,996V**. Explain why this 10% drop in voltage prevents the oil droplets from igniting instantly, causing fuel to "puddle" in the chamber.

BTU MATH Examples:

- BTU conversions using oil nozzle ratings and oil pump pressure.
- Using **Hertz (Hz)** to calculate the RPM of a motor controlled by a VFD to meet varying load demands.

<u>Suggested Resources</u>

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 31 Oil Heat w/ A/C

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 42 Oil Fired Heat

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 32 Oil Heat

Beckett/ Carlin Manuals

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0791 Oil Burner Controls & Servicing

VOG Portfolio Collection Examples

VOG Trait: A Problem Solver

- **Example:** When a Building Automation System (BAS) fails to engage the "Economizer" mode, the student uses a laptop to interface with the controller. They identify a faulty outside air enthalpy sensor and manually override the logic to ensure the building stays pressurized while awaiting parts.

VOG Trait: A Critical Thinker

- **Example:** The student explains the "Affinity Laws" in relation to Variable Frequency Drives (VFDs), calculating how dropping a fan's speed by 20% can reduce power consumption by nearly 50%, and justifies the ROI (Return on Investment) to a mock building owner.

VOG Trait: Work Ready

- Students can show pictures of themselves replacing oil nozzles or recording cad cell readings using a multimeter.

Priority Standard 12-5: Industry EPA standards for safety and environmental issues regarding refrigerant.

Big Idea(s):

1. **EPA regulations promote sustainability, and HVAC professionals must follow these guidelines to minimize environmental harm and maintain certification.**

Essential Question(s):

1. **Can you describe proper safety techniques that go with handling refrigerants?**

Learning Outcomes

Students will know:	*As evidenced by:*
12-5.A EPA certification requirements • **Type I** • **Type II** • **Type III** • **Universal**	1. **Explain differences in certification types.** 2. **Decide which type is right for them**
12-5.B Proper storage and handling of refrigerants.	1. **Explain safe refrigerant handling and applications**
12-5.C Isolate system components.	1. **Describe and demonstrating how to isolate system components according to EPA regulations**
12-5.D Manually pump down a system	1. **Demonstrate manual pump down of systems.**
12-5.E Recycled and reclaimed refrigerant.	1. **Describe system dependent and self-contained recovery equipment**
12-5.F System recovery	1. **Demonstrate proper system recovery with different methods available**
12-5.G Perform the methods of determining when a recovery cylinder is full	1. **Determine when a recovery cylinder is full or will be full.**

12-5.H Problems associated with contaminants left in a refrigerant system after recovery	**1. Describe the problems associated with contaminants left in a refrigerant system after recovery.**
12-5.I Problems associated with mixing of refrigerants	**1. Explain the problems associated with mixing of refrigerants and how to deal with mixed refrigerants**
12-5.J Charge a system using; Frost pattern, Weight, Pressure/temperature including superheat/sub-cooling	**1. Demonstrate proper system charging**
12-5.K ASHRAE Refrigerant Safety Classifications of Refrigerants for Toxicity and Flammability.	**1. Explain the different classes of refrigerants, physical and chemical properties**

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• Capture • Chlorine • Global warming • Hazardous waste • Reclaim • Recover • Recycle • Refrigerants	• Ozone depletion potential (ODP) • Global warming potential (GWP) • De minimus • EPA certification • Universal certification • Active recovery • Atmospheric balancing	• Active recovery • Back seated valve • Front seated valve • Clean Air Act (CAA) • Environmental Protection Agency (EPA) • CFC • HFC • HCFC • Mid-seated valve • Low-loss fitting • Motor vehicle air conditioning (MVAC) • Passive recovery

		• Recovery cylinder • Montreal Protocol • Pump down

Trade Math Crossover:

1. Calculating Annual Leak Rates (The EPA Rule)

The EPA mandates that systems containing **50 lbs. or more** of refrigerant must be repaired if they exceed a specific annual leak rate.

- **The Categories:** * Commercial Refrigeration: **20%**
  - Industrial Process Refrigeration (IPR): **30%**
  - Comfort Cooling (Chillers/AC): **10%**
- **The Formula:**

Leak Rate % = (Lbs. of Refrigerant Added ÷Total System Charge) times (365 Days since last addition) times 100.

- **The Scenario:** A grocery store rack holds **450 lbs.** of R-404A. A technician adds **15 lbs.** to top it off. It has been **90 days** since the last time refrigerant was added.
- **The Math:** 1. Base Ratio: 15 ÷ 450 = 0.0333

2. Time Factor: 365 ÷ 90 = 4.05

3. Annualized Rate: 0.0333 times 4.05 times 100 = **13.5%**

- **The Compliance Check:** Does this exceed the **20%** limit for commercial refrigeration? (No, but it is approaching it).

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2. Recovery Cylinder Safety: The 80% Fill Limit

To prevent tanks from exploding due to hydrostatic pressure (liquid expansion when it gets hot), the EPA and DOT forbid filling a tank past 80% of its **Water Capacity (WC)** by weight.

- **The Data:** * **WC (Water Capacity):** 47.7 lbs.
  - **TW (Tare Weight/Empty Tank):** 28.1 lbs.
  - **Refrigerant SG (Specific Gravity):** 0.8

- **The Math:** 1. Maximum Refrigerant Weight: 47.7 times 0.80 = **38.16** lbs.

2. Total Scale Weight: 38.16 (gas) + 28.1 (tank) = **66.26** lbs.

- **The Field Safety:** If your scale reads **70 lbs.**, you have violated EPA safety standards and created a "liquid-full" bomb in your van.

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3. Vacuum Requirements for De-Minimis Release

The EPA allows for a "de-minimis" (tiny) release of refrigerant during service, but only if the proper vacuum levels were achieved during recovery.

- **The Rule:** For a medium-pressure appliance (like R-22 or R-410A) with more than 200 lbs. of charge, you must pull **10 inches of Mercury (Hg)** vacuum.
- **The Scenario:** You are recovering from a 300-lb chiller. Your gauge reads **5" Hg**.
- **The Math:** If 29.9" Hg is a perfect vacuum, and you are only at 5" Hg, calculate the percentage of total vacuum achieved compared to the legal requirement (5 ÷ 10 = 50%).
- **The Legal Result:** You must continue recovering for another 5" Hg before you can legally open the system to the atmosphere.

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4. GWP (Global Warming Potential) and Carbon Equivalency

12th graders must understand the "Phase-down" of HFCs. We measure environmental impact in **CO2 Equivalents**.

- **The Data:** * **R-410A GWP:** 2,088
    - **R-32 GWP:** 675
- **The Scenario:** A residential system leaks **8 lbs.** of refrigerant.
- **The Math:** 1. **R-410A Impact:** 8 lbs. times 2,088 = **16,704 lbs**. of CO_2

2. **R-32 Impact:** 8 lbs. times 675 = **5,400 lbs.** of CO_2

- **The Comparison:** By switching to the newer R-32 refrigerant, the environmental "damage" of a leak is reduced by what percentage? (16,704 - 5,400 ÷ 16,704).

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5. Mixed Refrigerant Math (The Economic/Environmental Loss)

The EPA strictly forbids mixing different refrigerants in a single recovery tank. Mixed gas cannot be reclaimed and must be destroyed by incineration.

- **The Scenario:** You have a 30-lb tank that is half-full of **R-22** 1,500 as reclaimed gas). A helper accidentally adds **2 lbs.** of **R-410A** to it.
- **The Math:** 1. The entire 17 lbs. is now "Contaminated."

2. Cost to destroy contaminated gas: **$5.00 per lb**.

3. Total Financial Loss: **$1,500 (lost value) + $85 (destruction cost) = $1,585**.

- **The Environmental Lesson:** Use the math to prove why "One Tank per Refrigerant" is the most important rule in the shop.

Sample Problems:

- Use tank weight listed on recovery bottles and calculate percentages to ensure they are not over filled.
- Converting **PSI to Inches of Water Column** (1 PSI = 27.7" w.c.) for high-pressure gas regulator settings.

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 13 Refrigerants
- Chapter 14 zeotropic Blends
- Chapter 15 Refrigerant recovery

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Section 4 Refrigerants

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 9 Refrigerant management

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0787 EPA Refrigerant Standards

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** The student calculates the "Total System Volume" of a hydronic loop to select the correctly sized expansion tank, ensuring the system can handle water expansion without triggering the 30-PSI relief valve.

VOG Trait: A Problem Solver

- **Example:** A student troubleshoots a "no heat" call on a steam boiler. They identify that the "Low Water Cut-Off" (LWCO) is fouled with sediment, preventing the burner from firing, and perform a professional "blow-down" and cleaning to restore service.

VOG Trait: An Effective Communicator

- **Example:** Demonstrate refrigerant handling tools for use, such as vacuum pump, scale, recovery machine.

VOG Project: Zero-Tolerance Recovery Simulation: Description: Students must demonstrate proper system recovery and charging while strictly following EPA regulations to prevent environmental harm. They must evaluate the risks of mixing refrigerants and use weight/pressure methods for precision. (VOG Alignment: Critical Thinker.)

<table>
<tr><th colspan="2">Priority Standard 12-6: Describe the mechanical refrigeration cycle and be able to troubleshoot problems.</th></tr>
<tr><td colspan="2">Big Idea(s):
1. Understanding the mechanical refrigeration cycle enables technicians to detect faults, make repairs, and ensure consistent system cooling.</td></tr>
<tr><td colspan="2">Essential Question(s):
1. How does understanding the mechanical refrigeration cycle help technicians diagnose and resolve common system malfunctions, and what are the key indicators of potential issues at each stage of the cycle?</td></tr>
<tr><td colspan="2">Learning Outcomes</td></tr>
<tr><td>Students will know:</td><td>As evidenced by:</td></tr>
<tr><td>12-6.A Refrigeration system's performance
● Evaporator
● Condenser
● Compressor</td><td>1. Demonstrate the proper use and installation of refrigeration gauges.
2. Verify a system is properly charged
3. Be able to explain testing procedures
4. Identify requirements to check evaporator performance
5. Identify requirements to check condenser performance
6. Identify requirements to check compressor performance</td></tr>
<tr><td>12-6.C Service valve positions
● Front seat, Mid seat, Back seat</td><td>1. Demonstrate how to front, mid and back seat position for proper operation of 3-way service valves.</td></tr>
<tr><td colspan="2">Link to Proficiency Scale</td></tr>
<tr><td colspan="2">Tiered Vocab- HVAC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:
• Tier 1: Common, everyday words (Basic communication).
• Tier 2: High-frequency academic words (Used across various subjects/trades).
• Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").</td></tr>
</table>

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Compressor • Condenser • Conduction • Convection • Evaporator • Reciprocating • Condensation • Refrigerant • Evaporation	• High-pressure side • Hot Gas discharge line • Liquid line • Low-pressure side • Pressure drop • Subcooled • Suction line • Superheat	• Accumulator • Crankcase heater • Cooling tower • Filter drier • Flash gas • Off cycle • On cycle • Liquid receiver • Series connection • Temperature difference (td) • Thermostatic expansion valve • Basic refrigeration cycle • Metering device

Trade Math Crossover:

1. Compression Ratio and Volumetric Efficiency

The compressor is the "heart" of the cycle. If the pressure difference between the high side and low side is too great, the compressor loses the ability to move mass (refrigerant).

- **The Formula:**

Compression Ratio = Head Pressure (PSIA) ÷ Suction Pressure (PSIA)

(Note: PSIA = PSIG + 14.7)

- **The Scenario:** An R-410A system is running with a dirty condenser coil.
  - Suction: **118 PSIG** (Saturation Temp: 40°F)
  - Head: **418 PSIG** (Saturation Temp: 120°F)
- **The Math:** 1. Convert to PSIA: 118 + 14.7 = 132.7 and 418 + 14.7 = 432.7.

2. Calculate the Ratio: 432.7 ÷ 132.7 = **3.26:1.**

- **The Troubleshooting:** If the ratio exceeds **5:1** for air conditioning, the discharge temperature will rise, carbonizing the oil. Use this math to explain why a "high head" condition leads to mechanical compressor failure.

---

2. Total Heat of Rejection (The Condenser's Job)

The condenser doesn't just remove the heat picked up in the house; it also has to remove the "Heat of Compression" added by the motor.

- **The Formula:**

Heat of Rejection = Evaporator Heat (BTUs) + Compressor Heat (Watts times 3.41)

- **The Scenario:** A 3-ton evaporator is absorbing **36,000 BTUs**. The compressor is drawing **2,800 Watts**.
- **The Math:** 1. Calculate Compressor Heat: 2,800 times 3.41 = **9,548 BTUs.**

2. Total Heat to Reject: 36,000 + 9,548 = **45,548 BTUs.**

- **The Engineering Logic:** If the condenser is only rated to reject 40,000 BTUs, use this math to predict what will happen to the Head Pressure and Subcooling.

Sample Problems:

- Measure line set length to determine correct number of ounces needed to properly charge refrigeration equipment.

Suggested Resources

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 53, 54 Trouble shooting Commercial systems

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Trouble Shooting & Typical Operating Conditions For Commercial Refrigeration

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0721 Refrigeration Special Systems

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** When evaluating a commercial walk-in freezer that is failing to maintain temperature, the student plots the system's performance on a Pressure-Enthalpy (P-H) Diagram. They analyze the "Compression Ratio" and determine if the compressor is inefficient or if the high discharge temperature is being caused by extreme "Suction Superheat."
- **Example:** The student differentiates between a "mechanical failure" (like a broken compressor valve) and a "thermodynamic failure" (like non-condensable in the system), using pressure fluctuations and temperature "glides" to justify their conclusion.

VOG Trait: A Problem Solver

- **Example:** A student encounters a system with "Hunting" expansion valves. Instead of immediately replacing the TXV, they troubleshoot the root cause—checking for proper sensing bulb contact, checking for "Flash Gas" in the liquid line, and verifying that the evaporator airflow is not restricted.
- **Example:** The student identifies a "Low Pressure" lockout. They use an ultrasonic leak detector or nitrogen isolation test to locate the leak, then calculate the exact amount of "Virgin Refrigerant" needed to restore the system to its nameplate charge after the repair.
- **Example:** Students can present a demonstration how to position service valves for gauge hookup

VOG Trait: Work Ready

- **Example:** The student demonstrates mastery of Deep Vacuum procedures, achieving a 500-micron pull-down and performing a "Standing Vacuum Test" to ensure the system is moisture-free and leak-tight before commissioning.
- **Example:** In their Digital Portfolio, the student documents a "Compressor Burnout" cleanup, showing the use of acid-test kits, suction-line filter driers, and oil-acid neutralizing agents to prove they can handle high-stakes commercial repairs.

Priority Standard 12-7: Testing procedures of an air-conditioning system	
Big Idea(s): 1. **Thorough start-up and testing procedures validate that air conditioning systems operate correctly and efficiently upon installation or service.**	
Essential Question(s): 1. **How do specific testing procedures for an air conditioning system ensure its optimal performance and longevity, and what are the key indicators that help technicians identify when the system is underperforming?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
12-7.A Tools and instruments needed for checking out air-conditioning and heating systems for proper operation. ● **Manifold Gauges** ● **Thermometers** ● **Amp meters** ● **Velocity meters** ● **Psychrometer** ● **Oil pump** ● **Leak detectors** ● **Micron meters**	1. **Use and demonstrate proper techniques with various tools and instruments needed for checking and testing combination air-conditioning and heating systems.**
12-7.B Air-conditioning components. ● **System Charge** ● **Motor Amperage** ● **Air flow** ● **Safety controls**	1. **Check system operation while following all safety procedures.** 2. **Determine equipment electrical, mechanical and code requirements.** 3. **Verify equipment air flow and distribution requirements.**

• **Voltages** • **3 phase motor rotation**	**4. Demonstrate checking operation of electrical control components such as isolating relays etc.** **5. Check for correct superheat and sub-cool, adjust to manufacturers' specifications**
12-7.C Methods for properly charging a system	**1. Demonstrate proper system charging by weight and superheat & sub-cooling, PT relationships**

Link to Proficiency Scale

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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Gas • Liquid • Refrigeration • Supply • Return • Register • Insulation • Thermostat	• Gauge pressure • Service valve • btu • Amperage • Vapor	• Saturated • Superheat • Sub cooling • Cfm • Heat gain • Solar gain • Watts • Liquid line • Suction line • Condensing unit • Air handler • Evaporator • Line set

Trade Math Crossover:

1. Troubleshooting with Superheat and Subcooling

This is the "Gold Standard" for 12th-grade diagnostics.

- **The Data (R-410A System):**
    - **Liquid Line Temp:** 90°F | **Liquid Saturation Temp:** 110°F
    - **Suction Line Temp:** 55°F | **Suction Saturation Temp:** 40°F
- **The Math:** 1. **Subcooling:** 110 - 90 = 20° F (High: Target is 10°F)

2. **Superheat:** 55 - 40 = 15° F (High: Target is 10°F)

- **The diagnosis:** High Subcooling + High Superheat = **Restriction** (usually a plugged TXV or filter drier). If it were a low charge, both numbers would typically be low or the superheat would be much higher.

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2. Calculating Evaporator Delta T (Sensible Heat)

To troubleshoot airflow versus refrigerant issues, you must calculate the temperature drop across the indoor coil.

- **The Formula:** CFM = Sensible Heat (BTU/h) ÷ 1.08 X Δ T
- **The Scenario:** A 3-ton AC (36,000 BTUs) is running. The return air is **75°F** and the supply air is **62°F**. The blower is moving **1,200 CFM**.
- **The Math:** 1. Calculate Actual Δ T: 75 - 62 = 13° F.

2. Calculate Expected Δ T: 36,000 ÷ (1.08 times 1,200) = 27.7° F.

- **The Troubleshooting:** Since the actual drop (13°F) is much lower than the expected drop (27.7°F), the math proves the coil is not absorbing heat. Is the coil bypassed, dirty, or is the compressor inefficient?

Sample Problems:

- Superheat/subcooling conversions, cfm calculations based on heat gain conversions.
- Calculating **Total External Static Pressure (TESP)** to diagnose duct restrictions or equipment failures.

Suggested Resources

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 16 System evacuation & Recharging

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 36 Refrigeration Applied to Air Conditioning

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 53, 54 Trouble shooting Commercial systems

Various Install Manuals from OEM Equipment

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0785 Air Conditioning

A0790 Forced Air Heating & Cooling

VOG Portfolio Collection Examples

VOG Trait: Work Ready

- **Example:** The student uses the "Square Root of 3" (1.732) formula to calculate the line current of a 3-phase motor. They compare their calculation to their actual clamp-on ammeter reading to verify the motor is not "single-phasing" or overloaded.
- **Example:** Using a phase-sequence meter, the student ensures that a new scroll compressor will rotate in the correct direction before applying power, demonstrating the "Measure Twice, Power Once" professional standard.
- **Example:** Perform an amp draw test of compressor while charging, demonstrate refrigerant manifold gauge use.

Priority Standard 12-8: Theory of a heat pump systems operation and its functioning ability

Big Idea(s):

1. **Heat pumps offer year-round comfort, and understanding their operation allows technicians to service systems that reduce energy use and carbon impact.**

Essential Question(s):

1. **What are the advantages of energy efficient systems?**
2. **How can an AC system be used to heat?**
3. **What differentiates the components of an AC system from the components of a heat pump?**
4. **Why must a heat pump must have a defrost cycle?**

Learning Outcomes

Students will know:	*As evidenced by:*
12-8.A Identify the components of the heat pump systems, • **Electrical** • **Defrost system** • **Reversing valve** • **Crankcase heater** • **Supplemental heat** • **Mechanical** • **Reversing vale** • **Metering devices** • **Check Valves**	**1. Ability to identify the components of the heat pump system and understand the difference compared to a standard air conditioning system.** **2. Explain the operation of the heat pump components**
12-8.B Heat pump system's performance	**1. Show understanding of COP and balance point, evaluating heat pump performance.**
12-8.C Recommend a repair, then validate and make the repair with proper trade techniques.	**1. Show troubleshooting techniques both in (electrical and mechanical) on a heat-pump system. (VOG-Problem Solver)**

12-8.D The history of heat pumps • **Air to air** • **Geothermal**	1. **Explain the history of heat pump systems as well as different types used.**

[Link to Proficiency Scale]

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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• charge • demand • defrost • Valve	• Air coil • Balance point • Air-source heat pump (ASHP) • Air-to-air heat pump • Air-to-water heat pump • Pilot-operated reversing • Heat pump • Compensator tank • Auxiliary heat • Reverse cycle	• Flow check piston • Ground coil • Ground loop • Indoor coil • Outdoor coil • riser • Water coil • Water loop • Biflow bypass TXV • Biflow metering TXV • Biflow thermostatic expansion valve • Closed-loop ground-source heat pump System • Direct-acting reversing valve • Direct exchange (DX) • Ground-source heat pump (GSHP) • Open-loop ground-source

		• Heat pump system • Water-source heat • Pump (WSHP

Trade Math Crossover:

1. The Balance Point Calculation

As the outdoor temperature drops, a heat pump’s ability to move heat decreases, but the house’s "Heat Loss" increases. The point where these two lines cross is the **Balance Point**.

- **The Data:** * House Heat Loss at 30°F: **35,000 BTUs/hr.**
    - Heat Pump Output at 30°F: **28,000 BTUs/hr.**
- **The Math:** 1. Calculate the **Heating Deficit** (35,000 - 28,000 = 7,000 BTUs/hr.

2. If the heat pump output drops by 500 BTUs for every 1°F drop in temperature, calculate the temperature where the deficit becomes zero (the Balance Point).

- **The Application:** Why must "Electric Strip Heat" (Auxiliary) turn on mathematically at this specific temperature?

---

2. COP: Efficiency vs. Electric Resistance

Seniors must prove that a heat pump is more efficient than a space heater, even in winter.

- **The Formula:** COP = Energy Out (BTUs) ÷ Energy In (Watts converted to BTUs
- **The Scenario:** A heat pump produces **32,000 BTUs** while consuming **3,800 Watts**.
- **The Math:** 1. Convert Watts to BTUs: 3,800 times 3.41 = 12,958 BTUs.

2. Calculate COP: 32,000 ÷ 12,958 = 2.47.

- **The Comparison:** Since a standard electric heater has a COP of **1.0**, calculate how many times more efficient the heat pump is. If the COP drops to 0.9 due to a dirty outdoor coil, is the heat pump still worth running?

Sample Problems:

- Calculate different size rooms for heat loss and then determine correct cfm needed for proper duct installations.
- Calculating **Total External Static Pressure (TESP)** to diagnose duct restrictions or equipment failures.

Suggested Resources

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 43 Air Source Heat Pumps

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 40 Heat Pumps

Heating & Cooling Essentials: ISBN 13: 9781631260599

- Chapter 33 Heat Pumps

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0785 Air Conditioning

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** The student evaluates a heat pump's performance using the **Coefficient of Performance (COP)** and **HSPF2** ratings. They explain how the "Balance Point" of a home—the outdoor temperature where the heat pump's capacity matches the building's heat loss—dictates when the system must engage auxiliary electric heat or a backup gas furnace.
- **Example:** The student analyzes the "Defrost Cycle" logic, explaining how the system temporarily switches back to cooling mode to melt ice off the outdoor coil and why the auxiliary heat must energize simultaneously to prevent blowing cold air on the occupants.

VOG Trait: A Problem Solver

- **Example:** A student encounters a heat pump that is "short-cycling" in heating mode. They use a multimeter to check the **Defrost Control Board** and sensors, identifying a faulty "Outdoor Coil

Thermistor" that is triggering unnecessary defrost cycles, and they recalibrate the system for proper operation.

- **Example:** The student identifies a "stuck" **Reversing Valve**. They demonstrate the ability to diagnose whether the failure is electrical (solenoid coil) or mechanical (internal slide), and they safely perform the recovery and brazing required to replace the valve without damaging the new component.

VOG Trait: An Effective Communicator

- **Example:** The student creates a "Homeowner Education Guide" that explains why a heat pump's supply air temperature (approx. 95°F) feels "cool" compared to a gas furnace (approx. 130°F), even though it is efficiently heating the home. They use clear language to manage customer expectations and promote energy-efficient habits.
- **Example:** Students could present the different components of a heat pump while describing their functions.

VOG Project: Energy Efficiency Comparison Study: Description: Students evaluate the performance of a heat pump versus a standard AC system, calculating the Coefficient of Performance (COP) and balance points to recommend energy-efficient repairs for a customer. **VOG** - **Problem Solver**.

Priority Standard 12-9: Systematically troubleshoot and service an air conditioning system.	
Big Idea(s): 1. **Advanced diagnostic skills in air conditioning systems reduce downtime and improve customer satisfaction through precise, timely repairs.**	
Essential Question(s): 1. **When troubleshooting for a suspected electrical problem, list a good step by step procedure to take us to the problem?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
12-9. Air conditioning systems performance and operating problems • **High, high side pressure** • **High, low side pressure** • **Low, high side pressure** • **Low, low side pressure** • **Improper pressure differential** • **Evaporator frosting** • **Air flow problems high and low side** • **Low voltages, control** • **High voltages, control** • **Open Electrical loads** • **Electrical Shorts** • **Contact resistance** • **Bad capacitors** • **Faulty starting components** • **Worn belts**	1. **Give an overview of the history as well as different types of air conditioning systems** 2. **Identify the components (electrical and mechanical) of the high efficiency air conditioning system and understanding the difference compared to a standard air conditioning system. (VOG-Critical Thinker)** 3. **Explain the operation of the components and typical failures of each.** 4. **Demonstrate troubleshooting techniques both in (electrical and mechanical) on an air conditioning system.** 5. **Demonstrate use of tools and test equipment following safety practices.**

• **Worn bearings**	
12-9.B Heating Systems repair	**1. Identify potential causes of system failure** **2. Describe how to correct problems** **3. Make repairs** **4. Explain why a component failed accurately**
12-9.C Air conditioning system problems	**1. Pass test on air conditioning system problems**
12-9.D Typical heating system problems	**1. Pass test on heating system problems**
12-9.E Electrical test instruments to diagnose electrical troubles	**1. Pass test on HVAC electrical problems** **2. Use electrical test instruments to diagnose electrical troubles and correct electrical system problems (VOG-Problem Solver)**

Link to Proficiency Scale

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Tier 1 (Everyday)	Tier 2 (Academic)	Tier 3 (Technical/Trade)
• Gas • Liquid • Refrigeration • Amperage • Register • Insulation • thermostat	• Gauge pressure • btu • Supply • Return • Watts • CFM • Vapor	• Service valve • Saturated • Superheat • Sub cooling • Heat gain • Solar gain • Condensing unit • Air handler • Evaporator • Line set

		• Liquid line • Suction line

Trade Math Crossover:

1. The Reversing Valve: Delta T Diagnostics

A leaking reversing valve allows hot discharge gas to "short circuit" back into the suction line, killing the system's efficiency.

- **The Rule:** The temperature difference between the suction line entering the valve and leaving the valve should be **less than 3°F**.
- **The Scenario:** * Temp In: **45°F** | Temp Out: **52°F**
- **The Math:** Calculate the **Heat Gain** (52 - 45 = 7°F).
- **The diagnosis:** Since 7°F > 3°F, the math proves the valve is leaking internally. Use this to explain why the compressor is running "hot" and the house isn't getting warm.

---

2. Defrost Cycle: Calculating Ice-Weight Impact

Heat pumps frost up in winter. A technician must understand the energy cost of the "Defrost Cycle."

- **The Scenario:** During defrost, the heat pump switches back to "Cooling Mode" to warm up the outdoor coil, but it turns on **15 kW** of electric heat to keep the indoor air from getting cold.
- **The Math:** 1. If the defrost cycle lasts **6 minutes** (0.1 hours), calculate the kWh consumed by the strips (15 kW} times 0.1 hrs. = 1.5 kWh).

2. If electricity costs **$0.18/kWh**, calculate the cost of a single defrost cycle.

- **The Maintenance Logic:** If a faulty sensor causes the unit to defrost 10 times a day unnecessarily, calculate the monthly waste for the homeowner.

Sample Problems:

- Use compressor ohm readings to determine run and start windings while wiring starting components.

Suggested Resources

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 54,54,55 Trouble shooting appendix B

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 41 Trouble Shooting

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0785 Air Conditioning

A0790 Forced Air Heating & Cooling

VOG Portfolio Collection Examples

VOG Trait: A Critical Thinker

- **Example:** When faced with a system that is "short-cycling," the student evaluates the entire cooling loop. They use a **Psychrometric Chart** to determine the enthalpy change across the coil, identifying that the issue isn't a faulty part, but rather an oversized system that is satisfying the thermostat before it can properly dehumidify the space.
- **Example:** The student differentiates between a "mechanical" restriction (like a plugged filter-drier) and a "thermodynamic" issue (like non-condensable in the line set) by analyzing the relationship between **Liquid Line Temperature** and **Condensing Pressure**.
- **Example:** Students can show evidence of condensing unit wiring highlighting contactor and capacitor wiring.

VOG Trait: A Problem Solver

- **Example:** The student encounters a "No Cooling" call where the compressor is humming but not starting. They systematically test the start capacitor, the run capacitor, and the compressor windings. Upon finding a "grounded" winding, they provide a cost-benefit analysis to the instructor (acting as the client) on replacing the compressor versus the entire outdoor unit.

- **Example:** Using a digital manometer, the student identifies that a high-head pressure issue is actually caused by a "static pressure" problem in the return ductwork, not a refrigerant overcharge. They solve the problem by adjusting the blower speed and cleaning the secondary heat exchanger.

VOG Trait: Work Ready

- **Example:** The student demonstrates mastery of the Recovery and Evacuation process during a major repair. They achieve a 500-micron vacuum and document the "decay test" results in their digital portfolio to prove the system is completely dehydrated and leak-free before recharging.
- **Example:** The student utilizes Bluetooth Smart Probes to sync system data to a tablet, creating a "Baseline Performance Report" that can be used for future preventative maintenance calls, a standard practice in high-end service companies.

Priority Standard 12-10: Become acquainted with hydronic heating systems	
Big Idea(s): 1. **Hydronic systems offer efficient, even heating, and understanding their components and applications expands a technician's skill set and service options.**	
Essential Question(s): 1. **If air needs to be removed from the system how do the circulator, air scoop and vent work together to purge out the air?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
12-10.A Components of hydronic heating systems.	**Explain the purpose of the hydronic heating system component.** 1. **Expansion tank** 2. **Air scoop** 3. **Auto feeder** 4. **Backflow preventer** 5. **Auto Vent** 6. **Bleeder** 7. **Flow check Valve** 8. **Circulator** 9. **Boiler P/T gauge** 10. **Pressure relief** 11. **Low water cut-off** 12. **Size Solar pump equipment and accessories based on manufacturers specifications for specific applications.** 13. **(Reference NABCEP 8.6, 8.7, 9.3) Determine pump location for solar thermal installations**

	14. Install the solar thermal pump according to the manufacturer's installation manual **15. Install photovoltaic module controller and pump**
12-10.B Requirements of water pressure in hydronic systems to ensure water will be at the highest point in a system	**1. Correct pressurizing a Hydronic system to insure water to proper level**
12-10.C Air bleeding a hydronic system	**1. Purge from a hydronic system**
12-10.D Anti-freeze protection	**1. Explain when anti-freeze is required**
12-10.E Effects of anti-freeze on heat transfer	**1. Explain how anti-freeze reduces the ability to transfer heat (specific heat is lower than water)**

[**Link to Proficiency Scale**]

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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	**Tier 2 (Academic)**	**Tier 3 (Technical/Trade)**
• DE aeration • Backflow preventer • Radiator • Steam	• Air bound • Air scoop • Air vent • aqua stat • Expansion tank • High limit control • Mixing valve • Water feeder • Circulator pump • Relief valve	• Condensing boiler • Conventional boiler • Dry-base boiler • Underfloor radiant heating system • Expansion steam trap • Fan convector • Flow-control valve • Direct return hydronic system

	• Zone valve • Series loop • Boiler drain • Low water cutoff	• Reverse return system • Thermostatic mixing valve • Two pipe hydronic system • Wet base boiler

Trade Math Crossover:

1. Calculating Required Flow Rate (GPM)

To heat a room properly, the pump must move a specific volume of water. If the water moves too slowly, the room stays cold; too fast, and the pipes will "whistle" (velocity noise).

- **The Scenario:** A high-efficiency boiler is supplying a baseboard loop that needs to deliver **40,000 BTUs**. The system is designed for a standard **20°F** temperature drop (Δ T).
- **The Math:** 1. Rearrange the formula: GPM = 40,000 ÷ (500 Times 20).

2. Calculate: 40,000 ÷ 10,000 = 4.0 GPM.

- **The Diagnostic:** If you measure the actual Δ T and find it is **35°F**, the math proves the water is moving too slowly. What is the actual GPM flowing through that pipe?

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2. Pump Head and Friction Loss

A circulator pump doesn't "lift" water (since it's a closed loop); it only overcomes the **friction** of the pipes. This is measured in **Feet of Head**.

- **The Data:** * 3/4" Copper Pipe at 4 GPM has a friction loss of **3 feet of head per 100 feet** of pipe.
  - Each 90° elbow is equivalent to **2 feet** of straight pipe.
- **The Scenario:** A loop has **150 feet** of pipe and **10 elbows**.
- **The Math:** 1. Total Equivalent Length: 150 + (10 times 2) = **170** feet.

2. Total Head Loss: 1.7 (hundreds of feet) times 3 (loss factor) = **5.1 feet of head.**

- **The Selection:** Use a "Pump Curve" chart to find a pump that can provide **4 GPM at 5.1 feet of head**.

Sample Problems:

- If we consider conventional baseboard to be rated at 500 BTUs per foot how much is needed in a room that requires 12000 BTUs?

Suggested Resources

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 39 Hydronic heating Fundamentals

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 33 Hydronic Heat

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0789 Heating Hydronic & Steam

VOG Portfolio Collection Examples

VOG Portfolio Examples:

1. Technical Literacy: The "Anatomy" of the Loop

A VOG-aligned technician doesn't see a "heater"—they see a **closed-loop thermal transfer system**. To be acquainted with hydronics, you must identify these components in a mechanical room:

- **The Prime Mover:** The **Circulator Pump**. It must overcome "Head Pressure" (friction loss) within the pipes.
- **Safety Critical:** The **Pressure Relief Valve (PRV)**, usually set to **30 psi** for residential systems, and the **Low Water Cut-Off (LWCO)** which prevents the boiler from firing if dry.
- **Air Management:** The **Air Scoops** and **Automatic Air Vents**. Air is the "enemy" of hydronics because it causes noise and stops heat transfer.

2. VOG Project Phase: System Mapping & Identification

In a VOG project, your first task is a **System Walk-Through**. You will be required to trace the "Supply" and "Return" lines and document the following variables:

The Temperature Differential (Δ T)

In a standard hydronic system, we aim for a specific temperature drop as the water travels through the house and returns to the boiler. This is expressed as:

Δ T = T supply – T return

- **VOG Standard:** A typical residential system targets a Δ T of **20°F** (11° C). If the Δ T is too small, the pump is moving water too fast; if it's too large, the water is moving too slow or the house is losing heat too rapidly.

VOG Trait: Work Ready

- **Example:** Students can present boiler piping projects including all necessary near boiler components.

Priority Standard 12-11: Startup and testing procedures of a hydronic system	
Big Idea(s): 1. **Testing and starting up hydronic systems ensure balanced operation and optimal performance across modern radiant heating installations.**	
Essential Question (s): 1. **How do the startup and testing procedures of a hydronic heating system ensure proper operation and system longevity, and what critical factors should technicians monitor during these processes to prevent potential system failures?**	
Learning Outcomes	
Students will know:	*As evidenced by:*
12-11A. Purge a hydronic system of air	1. **Use proper techniques to correctly purge hydronic systems of air.**
12-11.B Water pressure in hydronic systems to ensure water will be at the highest point in a system	1. **Correct pressurizing a hydronic system to insure water to proper level**
12-11.D Anti-freeze protection requirements	1. **Explain when anti-freeze is required**
12-11.E Anti-freeze on heat transfer	1. **Explain how anti-freeze reduces the ability to transfer heat (specific heat is lower than water)**
12-11.F Anti-freeze protection level testing	1. **Explain how to test anti-freeze level with appropriate tester**
Link to Proficiency Scale	

Tiered Vocab- HVAC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:

- Tier 1: Common, everyday words (Basic communication).
- Tier 2: High-frequency academic words (Used across various subjects/trades).
- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

Tier 1 (Everyday)	**Tier 2 (Academic)**	**Tier 3 (Technical/Trade)**

• Backflow preventer • DE aeration • Relief valve • Radiator • Steam	• Boiler drain • Air bound • Air scoop • Air vent • aqua stat • High limit control • Mixing valve • Series loop • Expansion tank • Water feeder • Circulator pump • Zone valve	• Direct return hydronic system • Reverse return system • Thermostatic mixing valve • Two pipe hydronic system • Wet base boiler • Condensing boiler • Conventional boiler • Dry-base boiler • Underfloor radiant heating system • Expansion steam trap • Fan convector • Flow-control valve • Low water cutoff

Trade Math Crossover:

1. Expansion Tank Sizing (Boyles' Law)

Water expands when heated. Since water is non-compressible, an expansion tank with a pressurized air bladder is required to prevent the "Relief Valve" from blowing.

- **The Scenario:** A system holds **30 gallons** of water. When heated from 60°F to 180°F, water expands by about **3%**.
- **The Math:** 1. Calculate the expanded volume: 30 times 0.03 = **0.9 gallons.**

2. If the expansion tank has a total volume of 2 gallons, calculate the percentage of the tank that will be filled with expanded water (0.9 ÷ 2.0).

- **The Safety Check:** If the air bladder in the tank fails and fills with water (waterlogging), explain using math why the system pressure will skyrocket the moment the boiler fires up.

2. Radiant Floor Spacing and Heat Flux

In modern hydronics, PEX tubing is embedded in floors. The closer the tubes, the more heat is delivered per square foot.

- **The Data:** * 6" spacing delivers **35 BTUs/sq ft**.
  - 12" spacing delivers **20 BTUs/sq ft**.
- **The Scenario:** A 400 sq ft room has a heat loss of **12,000 BTUs**.
- **The Math:** 1. Calculate the required "Heat Flux": 12,000 ÷ 400 = **30 BTUs/sq ft.**
- **The Design Decision:** Which spacing must the technician use to ensure the room stays warm on the coldest day of the year?

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3. Air Scoop and Velocity Math

Air is the enemy of hydronic systems. To remove air, the water must move slowly enough for bubbles to "float" into an air separator, but fast enough to carry heat.

- **The Rule:** Ideal velocity in a 3/4" pipe is **2 to 4 feet per second (fps)**.
- **The Formula:** V = GPM times 0.408) ÷ d^2 (where d is the internal diameter).
- **The Scenario:** You are pushing **8 GPM** through a 3/4" pipe (0.75").
- **The Math:** 1. Calculate Velocity: (8 times 0.408) ÷ 0.5625 = **5.8 fps.**
- **The Conclusion:** Since 5.8 > 4.0, the water is moving too fast. The air bubbles will be "whipped" into the water and won't be caught by the air scoop. How would upsizing the pipe to 1" change the velocity?

Sample Problems:

- Using boiler psi how much is needed to raise water 20 feet?

Suggested Resources

Modern Refrigeration & Air Conditioning ISBN 13: 9781631263545

- Chapter 39 Hydronic heating Fundamentals

Refrigeration and Air Conditioning Technology ISBN 13: 978-1-111-64447-5

- Unit 33 Hydronic Heat

Burnham Heating Helper

OSHA.Gov:

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10593

Apprenticeship Correlation

A0789 Heating Hydronic & Steam

VOG Portfolio Collection Examples

VOG Portfolio Examples:

Project 1: The "Cold-Fill" & Static Pressure Test

Before the burner ever ignites, the system must be hydraulically sound. This project focuses on the initial water charge and leak detection.

- **VOG Trait: A Critical Thinker:** Ensure the **Auto-Fill Valve** (Pressure Reducing Valve) is set to the building's static height requirement.
- **The Procedure:** 1. Close all drain valves and open the main water feed.

  2. Observe the **Tridicator Gauge** (the combo pressure/temp gauge).

  3. **Standard Check:** A typical 2-story home requires ~12 psi (83 kPa) cold.

  4. **The Test:** Perform a 15-minute static hold. If the needle drops, there is a "weep" or leak in a fitting that must be torqued before heat is applied.

Project 2: Systematic "Purge & Bleed" (Air Removal)

Air is the #1 cause of "No Heat" calls. This project teaches the VOG-standard method of purging a multi-zone system.

- **VOG Trait: Work Ready:** Clear all "air-bound" loops so the pump operates silently and efficiently.
- **The Procedure:**
  1. Isolate all zones except one.
  2. Connect a hose to the **Drain Valve** on the return manifold.

3. Force water through that single loop until the discharge into a bucket is a steady stream with no "spitting" or bubbles.
4. Repeat for each zone.

- **The Science:** Trapped air acts as a physical block. Because water is non-compressible but air is, an air bubble can literally stop a 1/20 HP pump from moving any fluid.

Project 3: Operational "Hot Test" & Delta-T Balancing

Once the system is full and quiet, we fire the boiler to test its thermal performance.

- **VOG Trait: A Problem Solver:** Verify that the system reaches the "High Limit" cut-off and that the **Expansion Tank** is absorbing the thermal expansion.
- **The Procedure:**
  1. Fire the boiler and monitor the temperature rise.
  2. Check the **Limit Control**: Most residential boilers should shut off the burner once they hit **180°F** to **200°F**.
  3. **Expansion Tank Check:** Watch the pressure gauge. As the temperature rises from 70°F to 180°F, the pressure should only rise by ~3–5 psi. If it spikes to 30 psi and the relief valve drips, the expansion tank is failed (waterlogged).
  4. **Temperature Balancing:** Use an infrared thermometer to measure the **Δ T** (T supply – T return) at the boiler.

VOG Trait: Work Ready

- **Example:** Students can present purging air from hydronic lines connected to a boiler.

Priority Standard 12-12: Workplace skills for inside and outside production and the possibility of Work based Learning (WBL)	
Big Idea(s): 1. Success in the workplace depends on understanding expectations, practicing safe and respectful behavior, and building strong communication and teamwork skills—both in the classroom and through real-world experiences like Work-Based Learning.	
Essential Question(s): 1. What are some possibilities that can happen if you disregard safety at a job site? 2. Could you explain safety and how it applies to the HVAC trade?	
Learning Outcomes	
Students will know:	*As evidenced by:*
12-12.A Work-based learning.	1. Define expectations of each partner. 2. Refer to the Work Study Guidelines for roles and expectations. 3. Come to work every day on time. 4. Take directions. 5. Motivateto accomplish the task at hand.
12-12.B The student contribution in the workplace	1. Formulate a list of what they can bring into the workplace and how each item may impact their job. School subjects; past experiences; self-concept and personality; needs, values and interests; knowledge skills and attitudes; career goals and plans. 2. Demonstrate contributing to the success of a team. 3. Read and interpret workplace documents. 4. Demonstrate ability to respond in writing clearly and concisely.
12-12.C Communication in the workplace.	1. Discuss verbal and non-verbal communication. List ways negative nonverbal communication may be displayed. 2. Role play ways of demonstrating effective verbal communication. 3. Contribute innovative ideas. 4. Work with initiatives and co-workers. 5. Communicate effectively with co-workers and customers.
12-12.D Create a student guide in preparation for an interview.	1. Outline and describe the three stages of an interview –greeting, exchange and parting. 2. Role playing the stages of the interview.

12-12.E Post interview process	**1. Follow-up activity after completion of the interview.** **2. Review an interview.**
12-12.F Develop a ready-made guide for the worksite.	**1. Discuss work site items: transportation; hours of work; absence and tardiness; conflict resolution; role of student, teacher, and workplace supervisor; dress code; job description; expectations**
12-12.G Discuss feedback from the work placement.	**1. Provide feedback about work placement.** **2. Understand the guidelines for placement.**

Link to Proficiency Scale

Trade Math Crossover

1. Labor Burden and Billable Rates

As a WBL student, your employer pays you a wage, but your "cost" to the company is much higher due to taxes, insurance, and fuel.

- **The Data:** * Your Wage: **$20/hr.**
  - Labor Burden (Taxes/Insurance): **25% of wage**
  - Overhead (Truck, Tools, Office): **$45/hr.**
- **The Math:** 1. Calculate your total hourly cost to the company: 20 + (20 times 0.25) + 45.

  2. Total Cost = **$70/hr**.

- **The Professional Lesson:** If the company bills the customer **$125/hr.** for your labor, calculate the "Net Profit" the company makes on you per 8-hour day. If you spend 2 hours "looking for parts" because your truck is messy, how much profit did the company lose?

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2. Production Efficiency (The "Install" Timeline)

In production housing, crews are given a "labor budget" (the number of hours allowed to finish a job).

- **The Scenario:** A lead tech and a WBL student are assigned to a "Rough-In." The labor budget is **16 man-hours**.
- **The Math:** 1. If the Lead Tech works 7 hours and the student works 7 hours, what is the total man-hours used?

  2. If they finish the job in that time, calculate the "Efficiency Percentage" (14 ÷ 16).

- **The Workplace Reality:** If the student works slowly and the job takes **10 hours** for the pair (20 total man-hours), the job is **25% over budget**. Use the math to explain why a "slow" student can make a job lose money even if their hourly wage is low.

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3. Material Waste and "The Bottom Line"

Quality employees in "Outside Production" minimize waste. Small mistakes in measurements lead to "scrap" that eats the profit margin.

- **The Scenario:** You are installing 200 feet of line set. Because of poor measuring, you waste **6 inches** of copper on every 10-foot connection.
- **The Math:** 1. There are 20 connections ($200 \div 10$).

  2. Total waste: 20 times 0.5 ft = 10 feet.

  3. If copper line set costs **$6.50 per foot**, calculate the "Waste Cost."

- **The Workplace Skill:** If the total profit for the install was only **$300**, what percentage of that profit was thrown in the scrap bin due to poor measuring?

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4. "Call-Back" Math (The Quality Employee Metric)

A "Quality Employee" does the job right the first time. A "Call-Back" is when a tech has to return to fix a mistake for free.

- **The Scenario:** You forgot to glue a PVC 90° elbow on a condensate drain. It leaks, and the company has to send a tech back to fix it.
  - **Cost of the fix:** 1 hour travel + 1 hour labor + $20 in fuel.
  - **Lost Opportunity:** While fixing your mistake, that tech *could* have been doing a **$180** maintenance visit.
- **The Math:** Calculate the "Total Loss" to the company for that one unglued fitting (70 cost} + 180 lost revenue).
- **The Goal:** How many days of "perfect" work does it take to earn back that **$250 loss** if the company only nets $30/day in profit from your labor?

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5. Work-Based Learning: Paycheck Deductions (The "Net" Reality)

Understanding your first professional paycheck is a critical workplace skill.

- **The Data (Weekly):**
    - Gross Pay: **$800** (40 hrs. @ $20/hr.)
    - Federal Tax: **12%**
    - FICA (Social Security/Medicare): **7.65%**
    - Health Insurance Deduction: **$45**
- **The Math:** 1. Calculate total percentage-based deductions: 800 times (0.12 + 0.0765) = **$157.20.**

  2. Calculate Net Pay (Take-home): 800 - 157.20 - **45.**

- **The Financial Skill:** What is your actual "Take-Home" hourly rate? Use this math to create a budget for your work vehicle's gas and insurance.

Sample Problems:

- Calculating ROI (Return on Investment) and energy savings for high-efficiency equipment upgrades.

VOG Portfolio Examples:

Project 1: The "Service Ticket" & Professional Documentation

In the field, your writing is as important as your wrench-work. A VOG technician must document every action to satisfy liability, billing, and safety audits.

- **VOG Trait: Effective Communicator:** Translate technical labor into a professional, client-facing service report.
- **The Procedure:** 1. **Drafting the Narrative:** Instead of writing "fixed leak," you write: *"Identified localized oxidation on 3/4" copper elbow; drained system zone 2, replaced fitting with Lead-Free Silvabrite solder, and re-pressurized to 12 psi."* 2. **Parts Inventory:** List every coupling, ounce of solder, and hour of labor. 3. **Client Sign-off:** Practice the "Soft Skill" of explaining the repair to a non-technical homeowner or building manager without using confusing jargon.

Project 2: Job Site Safety Audit (Inside/Outside Production)

Whether you are inside a cramped mechanical room or outside installing a rooftop unit (RTU), the VOG standard requires a **JHA (Job Hazard Analysis)** before work begins.

- **VOG Trait: Work Ready:** Identify environmental hazards specific to hydronic and HVAC work.
- **The Procedure:** Create a checklist for a hypothetical WBL site:
  - **Inside:** Check for adequate ventilation (CO concerns), confined space egress, and electrical lockout/tagout (LOTO).
  - **Outside:** Check for ladder safety (3-point contact), overhead power lines, and weather-related slip hazards.
  - **PPE Verification:** Confirm the use of safety glasses, gloves for handling hot pipes/flux, and steel-toed boots.

Project 3: The WBL "Bridge" (Resume & Portfolio)

This project prepares you for the **Work-Based Learning** application process. You aren't just looking for a job; you are presenting yourself as a low-risk, high-value asset.

- **VOG Trait: A Problem Solver:** Assemble a "Technical Portfolio" that proves you have met the 12-10 and 12-11 standards.
- **The Components:**
  - **Skills Matrix:** A list of systems you can identify (e.g., Cast Iron Boilers, PEX Manifolds, Zone Valves).
  - **Certifications:** Include your OSHA-10, EPA 608 (if applicable), or any manufacturer-specific training.

- **The "Elevator Pitch":** A 30-second spoken summary of your vocational path: *"I am a pre-apprentice specializing in hydronic system startup and testing, with a focus on energy efficiency and code compliance."*

Appendix

Link to NABCEP Solar Thermal Strands

Link to CTECS Licensed Trade VOG Guides & Resources

Link to Instructional Guidebook Resources

CTECS HVAC

Grade 9 Math/Trade Crossover

In the 9th-grade year, the focus is on "***Foundational Competencies***," where students transition from general middle-school math to the specific precision required for a licensed trade. In addition to the embedded competencies located throughout the curriculum the following **CTECS HVAC Curriculum**, **Grade 9 Math Connection Master Review Table is located below**. This alignment focuses on the: foundations of the trade safety, measurements, and basic theory; while mapping them to the **International Mechanical Code (IMC)**, **International Residential Code (IRC)**, and **OSHA 29 CFR 1926**:

Grade 9 Math Connection Master Review Table

Priority Standard	Math Domain	Real-World Trade Application	Code / Regulation Reference
9.1: Shop & Work Site Safety	**Ratios & Proportions**	Calculating the **4:1 ladder safety ratio** to ensure a stable climbing angle for roof access.	**OSHA 1926.1053(b)(1)**
9.1: Shop & Work Site Safety	**Linear Measurement**	Ensuring a ladder extends at least **3 feet** above a landing or roof edge for safe egress.	**OSHA 1926.1053(b)(1)**
9.3: Hand & Power Tools	**Fractions & Decimals**	Converting between fractional and decimal measurements (e.g., 1/4" = 0.25") for precision drilling and anchoring.	**IMC Chapter 3** (General Regulations)
9.5: Copper Tubing & Fittings	**Geometry & Addition**	Calculating the "Take-off" for copper fittings to determine the exact cutting length of tubing.	**IRC Chapter 12** (Mechanical Piping)
9.6: Heat Energy & Pressure	**Algebraic Subtraction**	Calculating **Δ-T (\Δ T)**, the temperature difference across a coil or heat exchanger.	**IMC Chapter 4** (Ventilation)

9.7: Sheet Metal Basics	**Area & Perimeter**	Calculating the surface area of a rectangular duct to determine the amount of metal required for fabrication.	**IMC Chapter 6** (Duct Systems)
9.8: Electrical Values & Circuits	**Algebraic Equations**	Solving for unknown variables (Volts, Amps, Ohms) using **Ohm's Law** to verify circuit safety.	**IRC Chapter 34** (Electrical)

Visualizing the 9th Grade Trade Math

- **Safety Tip (9.1):** To find the correct distance from the wall, students divide the height of the ladder's contact point by 4. If the ladder touches the building at 20 feet, the base must be exactly 5 feet away.
- **Theory Tip (9.6):** A "Δ-T" of 18–22 degrees are often the target for a cooling system. Students learn that Supply Temp - Return Temp = \Δ T.
- **Fabrication Tip (9.7):** To make a 12" x 12" duct, students must calculate the perimeter (12 + 12 + 12 + 12 = 48) and then add an extra inch for the "Pittsburgh" or "S-Cleat" seams.

Student "Quick-Check" Challenges

1. **The Ladder Challenge:** You are accessing a rooftop unit (RTU) that is 24 feet high. How far from the wall should the base of your ladder be, and how high must the top of the ladder extend past the roof edge? (Answer: 6 feet away from wall; 3 feet above the roof).

2. **The Sheet Metal Challenge:** You need to build a square plenum that is 20 inches on all sides. What is the total "stretch-out" length of the metal before you add your seam allowance? (Answer: 80 inches).

3. **The Ohm's Law Challenge:** A heating element has a resistance of 12 Ohms and is connected to a 120V circuit. How many Amps is the heater drawing? (Calculation: 120 \ 12 = 10 Amps).

CTECS HVAC

Grade 10 Math/Trade Crossover

For Grade 10 HVAC, the curriculum shifts from basic hand tools to the Physics of Refrigeration and Residential Systems. The math becomes more technical, requiring students to calculate system health using pressures and temperatures, while adhering to the Environmental Protection Agency (EPA) Section 608 regulations for refrigerant handling.

Grade 10 Math Connection Master Review Table

Priority Standard	Math Domain	Real-World Trade Application	Code / Regulation Reference
10.2: Refrigeration Theory	**Algebraic Equations**	Calculating **Superheat** and **Subcooling** to determine if a system has the correct refrigerant charge.	**IMC Chapter 11** (Refrigeration)
10.3: EPA Section 608	**Percentages & Volume**	Calculating the **80% Fill Level** for recovery cylinders to prevent over-pressurization and explosions.	**EPA 40 CFR Part 82, Subpart F**
10.4: Recovery & retrofit	**Subtraction & Net Weight**	Calculating the amount of refrigerant recovered by subtracting "Tare Weight" from "Gross Weight."	**EPA Section 608**
10.5: Residential Systems	**Ratios & Slope**	Calculating the proper pitch (1/8" or ¼” per foot) for condensate drain lines to prevent water damage.	**IRC Chapter 14** (Heating/Cooling)

10.6: HVAC Electrical	**Algebra (Power)**	Using **Watt's Law** to determine the total power consumption of a residential condensing unit.	**IRC Chapter 34** (Electrical)
10.7: Controls	**Linear Measurement**	Ensuring thermostat and sensor placement meets **ADA height requirements** for accessibility.	**OSHA 1926 / ADA Standards**

Visualizing the Grade 10 HVAC Math

- **Theory Tip (10.2):** This is the "***Essential Required Knowledge***" of HVAC math. Students find the system's pressure on the chart to determine the **Saturation Temperature**. They then subtract this from the actual pipe temperature to find **Superheat**.
- **EPA Tip (10.3):** Students must calculate: (WC X 0.8 X Specific Gravity) +Tare Weight. This ensures the tank never exceeds 80% liquid capacity, leaving room for vapor expansion as temperatures rise.
- **Code Tip (10.5):** According to the **IRC**, condensate must be "trapped" and sloped. Students use a torpedo level to ensure a 1/4" drop for every foot of horizontal run to ensure gravity moves the acidic water out of the building.

Student "Quick-Check" Challenges

1. **The EPA Fill Challenge:** You have a recovery cylinder with a Water Capacity (WC) of 30 lbs. and a Tare Weight (TW) of 18 lbs. If you are recovering R-410A (which has a safety factor roughly equal to water), what is the maximum "Gross Weight" the scale should show before you stop? (Calculation: (30 times 0.8) + 18 = **42 lbs.).**
2. **The Superheat Challenge:** Your suction line pressure is 118 PSI (which equals 40°F on the PT chart). Your actual thermometer reading on the pipe is 52°F. What is your Superheat? (Calculation: 52 - 40 = **12°F**).

3. **The Wattage Challenge:** A residential furnace blower motor draws 6 Amps on a 120V circuit. How many Watts is the motor consuming? (Calculation: 6 times 120 = **720 Watts**).

CTECS HVAC

Grade 11 Math/Trade Crossover

The CTECS HVAC Curriculum, Grade 11 is the year of **System Design and Load Calculation**. The math moves from the "internal" physics of the machine to the "external" physics of the building. Students must now calculate how much heat a structure loses or gains to properly size equipment according to **Manual J**, while ensuring compliance with the **IMC**, **IRC**, and **OSHA**.

Grade 11 HVAC Math Connection Master Review Table

Priority Standard	Math Domain	Real-World Trade Application	Code / Regulation Reference
11.2: Comfort & Psychrometrics	**Data Interpretation**	Using **Psychrometric Charts** to calculate Enthalpy and Relative Humidity for indoor air quality.	**IMC Chapter 4** (Ventilation)
11.3: Sizing & Load Calc	**Geometry & Algebra**	Performing **Manual J** calculations: summing the "Heat Transfer Multipliers" (HTM) for walls, windows, and doors.	**IRC Chapter 14** / ACCA Manual J
11.3: Sizing & Load Calc	**Volume & Ratios**	Calculating **Air Changes Per Hour (ACH)** to meet minimum fresh air requirements.	**IMC Table 403.3.1.1**
11.4: Duct Design	**Friction & Area**	Using a **Duct Calculator (Ductulator)** to find friction loss per 100 ft of duct based on CFM and velocity.	**IMC Chapter 6** / ACCA Manual D
11.5: Indoor Air Quality	**Percentages**	Calculating the percentage of "Outside Air" vs. "Return Air" for economizer operation.	**IMC Chapter 5** (Exhaust Systems)

11.7: Piping & Hydronics	**Fluid Dynamics**	Calculating **GPM (Gallons Per Minute)** required for hot water coils based on BTU load.	**IRC Chapter 21** (Hydronics)
11.8: Safety & Rigging	**Weight & Force**	Calculating the **Safe Working Load (SWL)** of ropes and slings when lifting heavy roof-top units (RTUs).	**OSHA 1926.251**

Visualizing the Grade 11 HVAC Math

- **Psychrometric Tip (11.2):** This is where students learn that "cooling" isn't just lowering temperature; it's removing **Latent Heat** (moisture). They use the chart to find the "Dew Point" to prevent condensation in ductwork.
- **Manual J Tip (11.3):** Students learn that a window has a different "U-Value" than a wall. They calculate: Area X U-Value X Δ T = Heat Loss. **Important Note** to ensure students understand: **Over-sizing equipment is now a code violation under the IECC**.
- **Duct Design Tip (11.4):** Air has friction. Students use the **Ductulator** to ensure the blower motor can actually "push" the required air through the ***"Equivalent Length"*** of the duct system.
- **Safety Tip (11.8):** Under **OSHA 1926**, students must understand that the "Angle of the Sling" changes the load. A 45-degree angle puts significantly more stress on a strap than a 90-degree lift.

Student "Quick-Check" Challenges

1. **The Manual J Challenge:** A room has 100 sq. ft. of glass with a U-Value of 0.5. If the temperature difference (ΔT) is 70°F, how many BTUs per hour are lost through that glass? (Calculation: 100 times 0.5 times 70 = **3,500 BTU/hr.).**

2. **The Ventilation Challenge:** A classroom requires 15 CFM of outside air per person. If there are 20 people, what is the total required Outside Air (OA) in CFM? (Calculation: 15 times 20 = **300 CFM).**
3. **The Rigging Challenge:** You are lifting a 2,000 lb. RTU with two slings. If the sling angle is 30 degrees, the tension on each sling doubles. What is the tension on each strap? (Answer: **2,000 lbs. per strap**).

CTECS HVAC

Grade 12 Math/Trade Crossover

In Grade 12, the **CTECS HVAC Curriculum** reaches the "Mastery" level. The focus shifts from residential units to **Commercial Systems**, **Chilled Water**, and **Industrial Control Logic**. The math requires a high degree of precision to ensure the safety of large-scale equipment and compliance with the **IMC**, **IRC**, **IFGC**, and **OSHA**.

Grade 12 Math Connection Master Review Table

Priority Standard	Math Domain	Real-World Trade Application	Code / Regulation Reference
12.2: Commercial Systems	**3-Phase Trigonometry**	Calculating Phase Angle and Power Factor for large 3-phase commercial motors.	**IRC Chapter 34**
12.3: Chilled Water	**Fluid Dynamics**	Calculating the **Pump Head** and GPM requirements for a multi-story chilled water loop.	**IMC Chapter 12** (Hydronics)
12.4: Advanced Controls	**Binary & Logic**	Programming VFDs (Variable Frequency Drives) using hertz (Hz) to control motor RPM and torque.	**IMC Chapter 11**
12.5: Fossil Fuel Systems	**Ratios & Volume**	Sizing high-pressure gas headers and calculating "Manifold Pressure" in inches of Water Column.	**IFGC Chapter 4** (Gas Piping)
12.6: Alternative Energy	**Geometry**	Calculating the optimal tilt angle for Solar Thermal collectors based on site latitude.	**IMC Chapter 14** (Solar)

12.8: Troubleshooting	**Algebraic Analysis**	Using "Total External Static Pressure" (TESP) to diagnose internal equipment failures.	**IMC Chapter 6** (Ducts)
12.11: Career Prep	**Financial Math**	Estimating "Total Cost of Ownership" (TCO) including labor, parts, and energy ROI for a client.	**Construction Management**

Visualizing the Grade 12 HVAC Math

- **Industrial Tip (12.2):** Students learn that 3-phase power provides a more constant flow of energy. They use the square root of 3 (1.732) in their formulas to calculate total Amperage: $I = VA / (E \times 1.732)$.
- **Troubleshooting Tip (12.8):** According to the **IMC**, duct systems must be sized for airflow. Students measure pressure before and after the coil/filter. If the **TESP** is higher than the data plate allows (typically 0.5" w.c.), they use math to determine if the duct is undersized or the coil is plugged.
- **Controls Tip (12.4):** Energy efficiency is math in motion. Students learn that dropping a fan's speed by 20% can reduce power consumption by nearly 50% (The Affinity Laws).
- **Fuel Gas Tip (12.5):** Under the **IFGC**, manifold pressure is critical. Students convert PSI to Inches of Water Column (1 PSI = 27.7" wc) to ensure the burner receives the precise amount of fuel for a clean "blue flame" combustion.

Student "Quick-Check" Challenges

1. **The 3-Phase Challenge:** A commercial rooftop unit is rated at 15,000 VA on a 208V, 3-phase circuit. What is the line current? (Calculation: 15,000 / (208 \times 1.732) = **41.6 Amps**).

2. **The Gas Pressure Challenge:** A boiler nameplate calls for 3.5" wc at the manifold. If your manometer reads 0.2 PSI, is the pressure too high or too low? (Calculation: 0.2 X 27.7 = 5.54" w.c. **Too High**).
3. **The Static Pressure Challenge:** You measure a Return Static of -0.2" wc and a Supply Static of +0.4" w.c. What is the Total External Static Pressure? (Calculation: 0.4 - (-0.2) = 0.6**" w.c.**).