



CTECS 9-12 Plumbing, Heating, Cooling Curriculum ©

CTECS 9TH – 12TH GRADE PLUMBING, HEATING & COOLING
CURRICULUM©

CTECS: CIARLEGLIO, PASQUALE (CO)

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

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CTECS Plumbing, Heating & Cooling

Contents

CTECS Instructional Model 6

Curriculum Introduction 7

Proficiency Scale Alignment 10

Durable AI Assignment **Error! Bookmark not defined.**

CTECS Plumbing, Heating and Cooling Capstone Project Integration .. **Error! Bookmark not defined.**

CTECS Plumbing, Heating and Cooling Math Integration & Competency Crosswalks..... 12

CTECS Plumbing, Heating and Cooling Philosophy 13

Program Description 13

CTECS Plumbing, Heating and Cooling Goals 15

Program Standards 17

Program Locations in CT 18

CT-DOL Program Approval 18

Curriculum Legend 19

CTECS Vision of a Graduate 20

 The CTECS Vision of the Graduate: A Roadmap for Instructional Excellence 20

CTECS Plumbing, Heating and Cooling Course Map 22

 Grade 9: Semester 1 22

 Grade 9: Semester 2 22

 Grade 10: Semester 1 23

 Grade 10: Semester 2 23

 Grade 11: Semester 1 24

 Grade 11: Semester 2 24

 Grade 12: Semester 1 25

 Grade 12: Semester 2 25

Grade 9 Curriculum 28

 Priority Standard 9.1 - Shop and site safety..... 28

 Priority Standard 9.2 - Plumbing and Mechanical trades licensing process and procedure. 32

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

| | |
|--|-----|
| Priority Standard 9.3 - Basic math skills, sketching and blueprint reading necessary in the Plumbing and Heating professions. | 36 |
| Priority Standard 9.4 - Plumbing & Mechanical codes | 40 |
| Priority Standard 9.5 - The proper use of the basic hand tools used In the Plumbing, Heating & Cooling Industry. | 43 |
| 1. Leverage and Torque (The Pipe Wrench) | 44 |
| 2. Precision Cutting and Kerf (The Hacksaw) | 44 |
| 3. The Geometry of the Tubing Cutter..... | 45 |
| 4. Leveling and Slope (The Torpedo Level)..... | 45 |
| Priority Standard 9.6 - Demonstration of student's proficiency in basic techniques used to join pipe. | 47 |
| Grade 10 Curriculum | 52 |
| Priority Standard 10.1 - Safety protocols and OSHA regulations..... | 52 |
| Priority Standard 10.2 - Proper installation practices of common piping systems..... | 55 |
| Priority Standard 10.3 - Plumbing Math and Science..... | 59 |
| Priority Standard 10.4 - Introduction to Pumping Systems..... | 62 |
| Priority Standard 10.5 - Residential Fixtures, Appliances, and Solar Thermal..... | 66 |
| Priority Standard 10.6- Employer expectations..... | 71 |
| Priority Standard 10-7 - Plumbing, Heating & Cooling Blue Print Reading | 75 |
| Priority Standard 10-8 - Repair and service of residential Plumbing, Heating & Solar Thermal Systems..... | 78 |
| Grade 11 Curriculum | 84 |
| Priority Standard 11-1: Safety expectations at the school and work sites..... | 84 |
| Priority Standard 11-2: Knowledge of basic electricity, electrical circuits and AC electric motors..... | 90 |
| 1. Advanced Electrical Logic (Standard 11-2)..... | 93 |
| Priority Standard 11-3: The use of building codes and manufacturers' installation instructions on current production jobs | 95 |
| Priority Standard 11-4: Calculate total heat gain/loss for the proper sizing of heating/cooling equipment. | 102 |
| Priority Standard 11-5: Airflow principles and design of air handling equipment. | 106 |
| Priority Standard 11-6: Work with fuel gases while comprehending industry environmental issues regarding storage and combustion..... | 110 |
| Priority Standard 11-7: Contemporary gas heating appliances..... | 114 |

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

| | |
|---|-----|
| Priority Standard 11-8: Ability to conduct a start-up on gas heating systems. | 119 |
| Priority Standard 11-9 Systematically troubleshoot and to service a gas system..... | 123 |
| Priority Standard 11-10: Handle refrigerants while comprehending industry environmental issues regarding them..... | 127 |
| Priority Standard 11-11: Refrigeration cycle and superheat, sub-cooling, and coil temperature differences..... | 133 |
| Priority Standard 11-12: Inside and outside production and the possibility of Work based Learning (WBL) | 138 |
| Grade 12 Curriculum | 142 |
| Priority Standard 12-1: Comprehend industry environmental issues regarding storage and combustion..... | 142 |
| Priority Standard 12-2: Contemporary oil heating appliances..... | 147 |
| 1. Nozzle Flow Rate and Net BTU Output | 149 |
| 2. Combustion Air and Excess Oxygen | 149 |
| 3. Pump Cut-Off and Vacuum Leak Detection | 149 |
| 4. Cad Cell Resistance and Flame Safety | 150 |
| 5. Net Stack Temperature and Efficiency Calculations | 150 |
| Priority Standard 12-3: Ability to conduct a start-up on oil heating systems..... | 153 |
| Priority Standard 12-4: Systematically troubleshoot and service an oil system. | 159 |
| Priority Standard 12-5: Industry EPA standards for safety and environmental issues regarding refrigerant..... | 164 |
| Priority Standard 12-6: Describe the mechanical refrigeration cycle and be able to troubleshoot problems..... | 170 |
| Priority Standard 12-7: Testing procedures of an air-conditioning system | 174 |
| Priority Standard 12-8: Theory of a heat pump systems operation and its functioning ability | 178 |
| Priority Standard 12-9: Systematically troubleshoot and service an air conditioning system..... | 183 |
| Priority Standard 12-10: Become acquainted with hydronic heating systems | 188 |
| Priority Standard 12-11: Startup and testing procedures of a hydronic system | 193 |
| Project 1: The "Cold-Fill" & Static Pressure Test | 196 |
| Project 2: Systematic "Purge & Bleed" (Air Removal) | 196 |
| Project 3: Operational "Hot Test" & Delta-T Balancing | 197 |
| Priority Standard 12-12: Workplace skills for inside and outside production and the possibility of Work based Learning (WBL)..... | 198 |

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

| | |
|---|-----|
| 1. Labor Burden and Billable Rates | 199 |
| 2. Production Efficiency (The "Install" Timeline) | 199 |
| 3. Material Waste and "The Bottom Line" | 200 |
| 4. "Call-Back" Math (The Quality Employee Metric) | 200 |
| 5. Work-Based Learning: Paycheck Deductions (The "Net" Reality) | 200 |
| Appendix | 203 |
| Link to NABCEP Solar Thermal Strands..... | 203 |
| Link to CTECS Licensed Trade VOG Guides & Resources..... | 203 |
| Link to Instructional Guidebook Resources..... | 203 |
| Grade 9 Math/Trade Crossover | 204 |
| Visualizing the 9th Grade Trade Math | 205 |
| Student "Quick-Check" Challenges | 205 |
| Grade 10 Math/Trade Crossover | 206 |
| Visualizing the Grade 10 Trade Math | 207 |
| Student "Quick-Check" Challenges | 207 |
| Grade 11 Math/Trade Crossover | 208 |
| Grade 11 Math Connection Master Review Table..... | 208 |
| Visualizing the Grade 11 Math..... | 209 |
| Student "Quick-Check" Challenges | 209 |
| Grade 12 Math/Trade Crossover | 211 |
| Visualizing the Grade 12 Math..... | 212 |
| Student "Quick-Check" Challenges | 212 |

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

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 |
|---|--|--|
| <p>Providing and Communicating Clear Learning Goals</p> <ol style="list-style-type: none"> 1. Providing scales and rubrics 2. Tracking student progress 3. Celebrating success <p>Using Assessments</p> <ol style="list-style-type: none"> 4. Using informal assessments of the whole class 5. Using formal assessments of individual students | <p>Conducting Direct Instruction Lessons</p> <ol style="list-style-type: none"> 6. Chunking content 7. Processing content 8. Recording and representing content <p>Conducting Practicing and Deepening Lessons</p> <ol style="list-style-type: none"> 9. Using structured practice sessions 10. Examining similarities and differences 11. Examining errors in reasoning <p>Conducting Knowledge Application Lessons</p> <ol style="list-style-type: none"> 12. Engaging students in cognitively complex tasks 13. Providing resources and guidance 14. Generating and defending claims <p>Using Strategies That Appear in All Types of Lessons</p> <ol style="list-style-type: none"> 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 | <p>Using Engagement Strategies</p> <ol style="list-style-type: none"> 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 <p>Implementing Rules and Procedures</p> <ol style="list-style-type: none"> 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 <p>Building Relationships</p> <ol style="list-style-type: none"> 38. Using verbal and nonverbal behaviors that indicate affection for students 39. Understanding students' backgrounds and interests 40. Displaying objectivity and control <p>Communicating High Expectations</p> <ol style="list-style-type: none"> 41. Demonstrating value and respect for reluctant learners 42. Asking in-depth questions of reluctant learners 43. Probing incorrect answers with reluctant learners |

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CTECS Plumbing, Heating & Cooling 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

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CTECS Plumbing, Heating & Cooling

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.

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CTECS Plumbing, Heating & Cooling

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.

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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.

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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 Plumbing, Heating & Cooling Proficiency Scales](#)

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

[VANGUARD Trades PS Implementation Guide](#)

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CTECS Plumbing, Heating and Cooling Math Integration & Competency

Crosswalks

To fully illustrate the rigorous mathematical foundations embedded within the *CTECS Plumbing, Heating and Cooling* 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 Plumbing, Heating and Cooling 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 DFU 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 Plumbing, Heating & Cooling Math Integration Guide](#)

[Access the Math/SAT/Code Crossover Guide](#)

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CTECS Plumbing, Heating & Cooling

CTECS Plumbing, Heating and Cooling Philosophy

The **PLUMBING, HEATING and Cooling** course of studies is designed to create an appreciation of the industry and to develop entry-level skills within the **PLUMBING, HEATING and COOLING** 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 **PLUMBING, HEATING and COOLING** 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 Cooperative Work Experience, employed by a licensed **PLUMBING, HEATING and COOLING** contractor or wholesale company.

Program Description

Students enrolled in the CTECS **Plumbing, Heating & Cooling** career program will obtain instruction and demonstrate skills and knowledge in construction safety, measuring and blueprint reading, calculations of plumbing, heating and cooling systems including; drainage fixture units, water supply fixture units, gas pipe sizing, 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, hybrid heat pump technology, gas, as well as oil heating systems.

Students in the **Plumbing, Heating & Cooling** program receive both on-site and off-campus jobsite learning opportunities simulating real-world applications. Students are instructed upon the installation and repair of water, waste, gas as well as mechanical systems such as installation and repair of refrigeration, heating, and cooling mechanical systems in both residential homes and commercial buildings.

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CTECS Plumbing, Heating & Cooling

In addition, students enrolled in the **Plumbing, Heating & Cooling** program will also obtain instruction in energy efficiency, environmental, renewable energy, as well as energy conservation practices. The systems that control indoor climate are constantly evolving to reflect technological advancements and environmental concerns.

The demand for plumbing, heating and cooling technicians is expected to outpace the supply of workers trained in this demanding but rewarding field. This career area is considered to be **“In-Demand, Job Growth”** Category as per CT-DOL. Plumbing, Heating & Cooling are licensed trades that requires not only highly technical knowledge and skill, but also a thorough understanding of the Connecticut adopted ICC Plumbing and Mechanical Codes.

Students receive up to 720 hours of related instruction upon successful completion of the program towards the P-2 and S-2 apprenticeship. Students may be able to receive 1500 hours towards a career affiliated apprenticeship upon graduation* (*Upon Employer Acceptance)

Students are eligible to participate in work-based learning (WBL) in grades 11 & 12. This program allows companies to hire students during the school day to work as a pre-apprentice in the Plumbing, Heating & Cooling industry. Students will receive CT-DOL approved credit for their work experience which is an important pipeline for getting our students into industry.

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CTECS Plumbing, Heating & Cooling CTECS Plumbing, Heating and Cooling Goals

The **CTECS PLUMBING, HEATING and COOLING** Program will create an awareness of opportunities within the vast trade areas that comprise the Plumbing, Heating and Cooling Industry. The program incorporates new developments and practices related to Plumbing, Heating and Cooling in residential and commercial installations.

Program Goals

As a result of education in the PLUMBING, HEATING and COOLING Program grades 9-12 Students will know or do:

- 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 Plumbing and PHC industry
- Understand joining methods for piping and sheet metal materials
- Study blueprints, design specifications, or manufacturers' recommendations to ascertain the configuration of Plumbing & PHC fixtures and appliances to ensure the proper installation. 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 safe hand/power tool uses and operations
- Identify, define and demonstrate the features and the regulations relating to water supplies.
- Design and Install drainage, waste, and vent piping systems according to code.
- Installation and Service Plumbing & PHC Components.
- Inspect, examine, or test installed systems or pipe lines, using pressure gauge, hydrostatic testing, observation, or other methods.

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CTECS Plumbing, Heating & Cooling

- Attach pipes to walls, structures, or fixtures, such as radiators or tanks, using brackets, clamps, tools, or welding equipment.
- Install pipes, fixtures, appliances, or equipment designed to reduce water or energy consumption
- Install pipe systems to support alternative energy-fueled systems, such as solar thermal systems, and heat pump water heaters.
- Install pipe systems to support conservation systems, such as rain-water and grey water systems.
- Install automatic controls to regulate pipe systems
- Installation of Fuel Gas. Demonstrate techniques in sizing and installing fuel gas systems.
- Design, Install and Service of Hydronic Heating Equipment and Systems (Oil, Gas)
- Design, Install and Repair gas and oil heating systems
- Prepare cost estimates for clients
- Present a Student Competency Checklist that is a purposeful collection of work that documents the student's efforts, progress or achievements in the PLUMBING, HEATING and COOLING trade during their four (4) years in the CTECS

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CTECS Plumbing, Heating & Cooling Program Standards

- Building Science Principles Certificate
- CT-DOL – Apprenticeship Related Instruction 720 Hours
- First Aid/CPR/AED credentialing
- Fall Protection Certification
- Lockout Tagout Certification
- OSHA – 10, 30 Certification – CFR – 1926
- Roth Oil Tank Certification
- Ladder Safety Certification
- CSST Gas Piping Certification
- Fluke Meter Certification
- PEX Tubing Certification
- Electrical PPE Safety Certification
- Powder Actuated Tools Certification

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CTECS Plumbing, Heating & Cooling Program Locations in CT

CTECS Plumbing, Heating and Cooling:

- [Oliver Wolcott Technical High School, Torrington](#)

CT-DOL Program Approval



The CTECS Plumbing, Heating and Cooling Curriculum is fully approved by the CT-DOL Office of Apprenticeship Training.

A CTECS Plumbing, Heating & Cooling graduate who ***successfully completes*** the program is entitled to 720 hours of related instruction training* towards a P-2 and up to an S-2 apprenticeship.

(*Contingent upon student receiving OSHA 30 certification)

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CTECS Plumbing, Heating & Cooling

| 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 (VOG) |

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CTECS Plumbing, Heating & Cooling

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:

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Vision of a Graduate

A CTECS Graduate is...

A Problem Solver

- Collaborative
- Practices creative, outside of the box thinking
- Can persevere and adapt
- Able to determine the root cause of issues
- Identifies multiple solutions and selects the most sensible approach
- Always follows through



An Effective Communicator

- Clearly and concisely conveys information for shared understanding
- Able to use multiple modes of communication
- Command of the language; written and verbal
- Actively listens



Respectful

- Embraces cultural diversity
- Practices kindness and consideration
- Understands and respects organizational structures
- Demonstrates professionalism
- Communicates with care and professionalism



Skilled Socially

- Uses effective verbal and non-verbal communication skills
- Ability to work as part of a team
- Interacts with diverse audiences in a manner appropriate for the setting
- Empathizes with and values others



A Critical Thinker

- Applies unbiased analysis and evaluation
- Evaluates sources of information for reliability
- Innovates
- Willing to adapt to new information and question things
- Makes rational decisions based on application of evidence and observation



Work Ready

- Motivated to continue learning
- Possess the knowledge and skills for industry area
- Models employability skills; i.e. punctual, dressed appropriately, dependable, good attitude and time management
- Strong work ethic



Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

CTECS Plumbing, Heating and Cooling Course Map

Grade 9: Semester 1

- 9-1 Introduce shop and site safety.
- 9-2 Plumbing & Mechanical trades licensing process and procedure.
- 9-3 Basic math skills, sketching and blue print reading necessary in the Plumbing, Heating & Cooling profession.
- 9-4 The various code books, and reference materials used in residential construction.
- 9-5 The proper use of the basic hand tools used in the Plumbing, Heating & Cooling industry.
- 9-6 Demonstration of student's proficiency in basic techniques used to join pipe.

Grade 9: Semester 2

- 9-1 Demonstrate Shop Safety & knowledge of site safety
- 9-1a-Working Safely with Solar Hot Water and Pool Heating Systems (Reference NABCEP 1.1,1.3- 1.5, 1.7, 1.8)
- 9-2 Plumbing & Mechanical trades licensing process and procedure.
- 9-3 Basic math skills, sketching and blue print reading necessary in the Plumbing, Heating & Cooling profession.
- 9-3a Conducting a Solar Thermal Site Assessment. (Reference NABCEP 4.1-4.9)
- 9-4 The various code books, and reference materials used in residential construction.
- 9-5 Demonstrate the proper use of the basic hand tools used in the Plumbing, Heating & Cooling industry.
- 9-6 Demonstration of student's proficiency in basic techniques used to join pipe.
- 9-6a-Installing Piping, Pipe Insulation and Connecting System Piping as it pertains to Solar Thermal installations. (Reference NABCEP 7.1-7.15)
- **End of Term DSA:** (Please refer to DSA Study Guide for in-depth topics listed on the

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

exam)

Grade 10: Semester 1

- 10-1 Safety protocol and OSHA
- 10-2 Common piping and installation practices of common piping used in the Plumbing, Heating & Cooling trades.
- 10-2a- Solar Thermal Piping: (Reference: NABCEP 7.16-7.26)
- 10-3: The relationship between math, science and the Plumbing, Heating & Cooling trade.
- 10-4: Introduction to Pumping Systems
- 10-5: Introduction to Residential Fixtures, Appliances, and Solar Thermal.
- 10-6: Employer expectations
- 10-7: BPR skills in the Plumbing, Heating & Cooling trades.
- 10-8 Repair and service of residential Plumbing, Heating & Solar Thermal Systems.
- **End of Term DSA:** (Please refer to DSA Study Guide for in-depth topics listed on the exam)

Grade 10: Semester 2

- 10-1 Demonstrate Shop Safety & knowledge of site safety
- 10-2 Common piping and installation practices of common piping used in the Plumbing, Heating & Cooling trades.
- 10-2a- Solar Thermal Piping: (Reference: NABCEP 7.16-7.26)
- 10-3: The relationship between math, science and the Plumbing, Heating & Cooling trade.
- 10-4: Introduction to pumping systems
- 10-4a- Installing Electrical Control Systems as it pertains to Solar Thermal Systems (Reference NABCEP 9.1, 9.2, 9.4-9.8)
- 10-5: Introduction to Residential Fixtures, Appliances, and Solar Thermal.
- 10-5a-Solar Thermal Systems and their components Reference (NABCEP 2.1-2.5)

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CTECS Plumbing, Heating & Cooling

- 10-5b-Installing Solar Hot Water Heaters and Storage Tanks. (Reference NABCEP 6.1-6.18)
- **End of Term DSA:** (Please refer to DSA Study Guide for in-depth topics listed on the exam)

Grade 11: Semester 1

- 11- 1 Demonstrate Safety in Construction Environment
- 11-1a-Installing Solar Collectors (Reference NABCEP 5.1-5.13)
- 11-2 Code related theory required to design a Plumbing, Heating & Solar Thermal system, including related math and science.
- 11-2a-Adapting a Solar Thermal System Design (Reference NABCEP 3.1-3.9)
- 11-6 Demonstrate Jobsite protocol, customer and employer expectations
- 11-6a-Customer Expectations as it pertains to Solar Thermal Installations. (Reference NABCEP 11.7-11.13)
- 11-7 Reading and interpreting Plumbing and Heating plans and specifications.
- 11-8 Employer expectations: the ability to find employment in the Plumbing, Heating & Cooling trade and become a quality employee.
- **End of Term DSA:** (Please refer to DSA Study Guide for in-depth topics listed on the exam)

Grade 11: Semester 2

- 11-1 Demonstrate Safety in Construction Environment
- 11-1a-Installing Solar Collectors (Reference NABCEP 5.1-5.13)
- 11-2 Code related theory required to design a Plumbing, Heating & Solar Thermal system, including related math and science.
- 11-2a-Adapting a Solar Thermal System Design (Reference NABCEP 3.1-3.9)
- 11-3 Installation, design, and layout of a DWV systems.
- 11-4 Theory requirements of the fuel gas code, including the venting of appliances.

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CTECS Plumbing, Heating & Cooling

- 11-5 Introduction of hydronic heating systems and components of both hot water and steam heating systems.
- 11-6: Delivery and storage of fuel oil in heating systems.
- 11-6a-Customer Expectations as it pertains to Solar Thermal Installations. (Reference NABCEP 11.7-11.13)
- **End of Term DSA:** (Please refer to DSA Study Guide for in-depth topics listed on the exam)

Grade 12: Semester 1

- 12- 1 Jobsite Safety on/off campus and WBL
- 12-1 Reinforce 9th, 10th and 11th grade safety issues and stress job site safety required for students performing production work.
- 12-2 Introduction to mechanical system blueprints.
- 12-3 BPR skills relating to plumbing systems in accordance with the International Plumbing Code
- 12-5 Installation and testing of heating systems and components
- 12-5a-Performing a Solar Thermal System Checkout, Reference: NABCEP 10.1,10.2,11.1-11.6
- **End of Term DSA:** (Please refer to DSA Study Guide for in-depth topics listed on the exam)

Grade 12: Semester 2

- 12- 1 Jobsite Safety on/off campus and WBL
- 12-2 Introduction to mechanical system blueprints.
- 12-4 Reinforce student achievement in a timed/graded activity.
- 12-5 Installation of hydronic heating systems and components.
- 12-5a-Performing a Solar Thermal System Checkout, Reference: NABCEP 10.1,10.2,11.1-11.6

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

- 12-6 Troubleshooting and testing of hydronic heating systems and components, including safety and operating controls.
- 12-7 Obtaining employment in the Plumbing, Heating & Cooling Trades.
- 12-8 Construction Management Opportunities in the Plumbing, Heating & Cooling Trades.
- **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

Plumbing, Heating & Cooling

Grade 9

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Grade 9 Curriculum

| Priority Standard 9.1 - Shop and site safety. | |
|--|---|
| <p>Big Idea(s):</p> <ol style="list-style-type: none"> 1. 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. 2. Safety is not just a set of rules but a continuous practice required to protect oneself and others in a high-risk environment. | |
| <p>Essential Question(s):</p> <ol style="list-style-type: none"> 1. How does practicing safe work habits help guarantee your future in the trade? 2. Why do you think that OSHA training is a requirement in order to be employed in the construction trade? | |
| Learning Outcomes | |
| <i>Students will know:</i> | <i>As evidenced by: (oral, written, or performance)</i> |
| <p>1. Safe Work Habits</p> <ul style="list-style-type: none"> ● Hand tools ● Portable power tools ● Stationary power tools ● Eye safety ● Potential work area safety risks ● Horseplay ● Potential injuries of unsafe work practices ● Hearing protection ● Proper clothing ● Removal of jewelry ● Ladders | <ul style="list-style-type: none"> ● Scoring 100% on all safety tests or retests. ● Model's safe practices: ● Collaborates with peers to ensure the safe use of tools and equipment. ● Identifies work areas that have potential safety risks. ● Discuss possible consequences of talking to a co-worker while using tools or throwing an object. ● Proper use of eye safety protection and hearing protection. ● Demonstrates the safe handling of hand tools and portable power tools. ● Listed safety rules for stationary and portable power tools ● Models a strong work ethic (VOG-Work Ready). |
| <p>2. Fire and Lockdown Procedures.</p> | <ul style="list-style-type: none"> ● Students identified locations of fire alarm pull stations, attenuators, and fire extinguishers. ● Demonstrates knowledge of evacuation routes and procedures. (VOG- Effective Communicator) |

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| <p>3. Correct procedure for dealing with an injury.</p> <ul style="list-style-type: none"> ● Puncture wounds ● Electric shock ● Trips and falls ● Blood borne pathogens ● Location of nurse's office. | <ul style="list-style-type: none"> ● Identifies that the cause of the injury is no longer a threat. ● Explain the dangers of coming in contact with the blood of an injured party (Universal Precautions.) ● Clearly communicated with the instructor(s) all injuries. ● Students identified location of eye wash stations, and power shut-off locations |
| <p>4. Appropriate clothing/equipment required to work on a construction site</p> | <ul style="list-style-type: none"> ● Wear appropriate clothing including: hard hat, safety glasses, hearing protection, safety shoes, gloves, etc. as required. |
| <p>5. Hazardous materials handling procedures.</p> | <ul style="list-style-type: none"> ● Explain purpose and application of SDS Sheets. ● Analyze a confined space and choose the proper procedures for entry ● Communicates with instructor to identify proper location of SOS Sheets (VOG-Effective Communicator) |
| <p>6. Proper lifting.</p> | <ul style="list-style-type: none"> ● Explain and demonstrate proper lifting Procedures. |
| <p>7. Solar Hot Water and Pool Heating Systems (Reference NABCEP 1.1,1.3- 1.5, 1.7, 1.8)</p> | <ul style="list-style-type: none"> ● Reference NABCEP 1.1,1.3- 1.5, 1.7, 1.8) ● Maintain safe work habits and clean, orderly work area ● Demonstrate safe and accepted practices for ● personnel protection ● Demonstrate awareness of safety hazards and how to avoid them ● Identify and implement appropriate codes and standards concerning worker safety and public safety ● Identify personnel safety hazards associated with solar thermal installations ● Identify environmental hazards associated with solar thermal installations through demonstrated awareness of pertinent Material Safety Data Sheets and other appropriate documents |

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CTECS Plumbing, Heating & Cooling

[Link to Proficiency Scale](#)

Tiered Vocab- Plumbing and Heating 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) |
|---|---|--|
| <ul style="list-style-type: none"> • Helmet • Warning • Ladder • Fire • Safe | <ul style="list-style-type: none"> • Hazard • Compliance • Precaution • Regulation • Inspect | <ul style="list-style-type: none"> • Ampere • PPE (Personal Protective Equipment) • SDS (Safety Data Sheet) • GFCI (Ground Fault Circuit Interrupter) • Lockout/Tagout (LOTO) |

Trade Math Crossover: [\(VOG- Problem Solver\)](#)

Focus: Ratios, load limits, and safety dimensions.

1. **The 4-to-1 Ladder Ratio:** To ensure a safe climbing angle, a ladder should be placed so that the base is 1 foot away from the wall for every 4 feet of height to the point where the ladder touches the structure. If a plumber needs to reach a pipe located 16 feet up a wall, calculate exactly how many inches the base of the ladder must be placed away from the wall to maintain this safety standard.
2. **Scaffolding Load Calculations:** A piece of scaffolding is rated for a maximum load of 500 lbs. If a 9th-grade student weighs 165 lbs. and their toolkit weighs 42 lbs., how many 20-foot lengths of Schedule 40 steel pipe (weighing approximately 2.17 lbs. per foot) can they safely bring onto the scaffolding before exceeding the safety limit?

Resources to compliment learning-

- OSHA CFR 1926,
- Modern Plumbing Textbook Chapter 1

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CTECS Plumbing, Heating & Cooling

Crossover to Apprenticeship Standards:

- A0099 Building Trades Safety OSHA 30 for construction certification

VOG Portfolio Collection Examples:

VOG- Critical Thinker

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

VOG Trait: Work Ready

- **Example:** A student consistently arrives at the shop with proper PPE (safety glasses, work boots, and appropriate clothing) and performs a "pre-flight" safety check of their workstation and tools without being prompted by the instructor.

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.

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Priority Standard 9.2 - Plumbing and Mechanical trades licensing process and procedure.

Big Idea(s):

1. Only licensed professionals and registered apprentices can legally perform trade work; the plumber's primary role is to "protect the health of the nation".

Essential Question(s):

1. Why do apprentices need to serve a 4-year apprenticeship?
2. Why is it important to adhere to testing requirements for the plumbing and mechanical trades?
3. How do the requirements needed to install Solar Thermal Systems vary by geographical area?
4. Why is it important to work collaboratively as a member of a team?

Learning Outcomes

| <i>Students will know:</i> | <i>As evidenced by: (oral, written, or performance)</i> |
|--|--|
| <p>1. Licensure Process in the State of Connecticut</p> <ul style="list-style-type: none"> ● Apprenticeship ● OJT ● Related Instruction ● Classroom Training ● Testing ● CEU's ● Solar Certification | <ul style="list-style-type: none"> ● List five job opportunities a student might pursue in our trade. ● Complete a web-based research paper on employment opportunities in the student's geographical area and one other area that appeals to the student. ● Identify several trade related job opportunities from a local newspaper and discuss why the student is qualified or not. ● Complete an essay describing why we say "The plumber protects the health of the nation" with supporting evidence. ● Complete a web-based research paper on the steps of the licensing process with regards to hours, record keeping and employee/employer responsibilities. ● Develop skills that will initiate motivation for continued learning. (VOG-Work Ready) ● Demonstrates basic problem-solving skills |
| <p>2. Code Identification as it relates to the solar trades. (Reference NABCEP 1.6)</p> | <ul style="list-style-type: none"> ● Identify and implement appropriate codes and standards concerning installation, operation and maintenance of solar thermal |

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CTECS Plumbing, Heating & Cooling

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| | systems and equipment. (Reference NABCEP 1.6) | |
| <p>3. Customer and employer expectations including the following:</p> <ul style="list-style-type: none"> ● Teamwork ● Coming to work on time ● Problem solving and using new ideas to come up with solutions ● Problem solving skills ● Technology to gain access to information | <ul style="list-style-type: none"> ● Explain the importance of coming to work/school every day on time ● Compose an essay on why it's important to be willing to take direction. ● Write an essay on importance of coming to work on time ● Explain Importance of contributing to a team and ensuring team members do not fail. ● Contributes new ideas and works with initiatives ● Selects and safely uses technological resources to accomplish work responsibilities in a productive manner. ● Respects organizational structures (VOG- Respectful) | |
| <p>Link to Proficiency Scale</p> | | |
| <p>Tiered Vocab- Plumbing and Heating students build a professional vocabulary, we have broken down the terms into three tiers based on the standard educational model:</p> <ul style="list-style-type: none"> ● 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"). | | |
| <p>Tier 1 (Everyday)</p> | <p>Tier 2 (Academic)</p> | <p>Tier 3 (Technical/Trade)</p> |
| <ul style="list-style-type: none"> ● Rules ● Test ● Job ● Permission ● Boss ● Paperwork, ● Law ● Hours | <ul style="list-style-type: none"> ● Compliance ● Certification ● Credential ● Authorization ● Supervision ● Documentation ● Statute ● Requirement | <ul style="list-style-type: none"> ● Jurisdiction ● Journeyperson Exam ● Apprenticeship ● Permit ● Master Plumber ● Affidavit of Experience ● Code (IPC/IRC/IMC) ● OJT (On-the-Job Training) |

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

Trade Math Crossover: **(VOG- Critical Thinker)**

Focus: Time management, apprenticeship hours, and record keeping.

1. Apprenticeship Progress Tracking:

A P-2 Journeyman license requires 720 hours of "Related Instruction" (classroom time) and 8,000 hours of On-the-Job Training (OJT). If a student completes 180 hours of instruction per school year, what percentage of the total required classroom hours will they have completed by the end of 9th grade?

2. OJT Accumulation:

If an apprentice works 40 hours per week for 50 weeks a year, how many years will it take them to reach the 8,000-hour requirement for their license? Express the answer in both years and total months.

Resources to compliment learning-

- Modern Plumbing Textbook (chapter 32)
- Mathematics for Plumbers and Pipefitters (unit 8)
- CTECS Licensed Trades VOG Resources

Crossover to Apprenticeship Standards:

- A0014 Plumbing Math

VOG Portfolio Collection Examples:

VOG: Work Ready

- Develop a flow chart listing the various stages of the licensure process.

VOG Trait: An Effective Communicator

- **Example:** A student can clearly explain the difference between a P-2 (Journeyman) and a P-1 (Contractor) license to a peer, including the specific on-the-job training hours and classroom requirements needed for each
- **Example:** The student practices a mock "elevator pitch" to a potential employer, articulately describing how their current CTECS coursework contributes to the 720 hours of related instruction required for their apprenticeship.

VOG Trait: A Critical Thinker

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

- **Example:** When reviewing the CT-DOL apprenticeship standards, the student analyzes how various certifications—such as **OSHA-10** or **PEX Tubing Certification**—increase their marketability and "value-add" to a future employer.

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CTECS Plumbing, Heating & Cooling

Priority Standard 9.3 - Basic math skills, sketching and blueprint reading necessary in the Plumbing and Heating professions.

Big Idea(s):

1. The ability to read blueprints and perform calculations in the Plumbing and Heating industry are crucial to a successful installation.
2. Accuracy in measurements and the ability to interpret blueprints are critical to the success and quality of any installation

Essential Question(s):

1. When measurements are not accurate, explain what you think can happen to the quality of the work?
2. What effect would the inability to properly read a blueprint have on the finished product of a building?
3. How does math impact the Plumbing and Heating trade on a daily basis?

Learning Outcomes

| <i>Students will know:</i> | <i>As evidenced by: (oral, written, or performance)</i> |
|---|--|
| 1. Basic math skills | <ul style="list-style-type: none"> ● Review fractions, mixed numbers, decimals, using appropriate teacher/text developed questions/examples. ● Develop a grasp of linear measurement as it relates to trade math. (End to center, center to center, pitch etc.) ● Review squares and square roots, cubes and cube roots, liquid measure and offsets. ● Apply unbiased analysis and evaluation to mathematically solve necessary calculations for pipe layout. (VOG) |
| 2. Sketching/blueprint reading skills required in every day trade practice. | <ul style="list-style-type: none"> ● Practice sketching plumbing installations using single line drawings. ● Identify fixtures, fittings, piping, valves, etc. from single line, detailed drawings and blueprints. ● Extract important information from |

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| | rough-in sheets and single line drawings. |
|---|--|
| <p>3. Solar Thermal Site Assessment. (Reference NABCEP 4.1-4.9)</p> | <ul style="list-style-type: none"> ● Conducting a Solar Thermal Site Assessment. (Reference NABCEP 4.1-4.9) ● Assess the required installation area, orientation, and tilt for proposed collector installation. ● Establish whether there is suitable installation area ● with unobstructed solar access for installing collector ● Investigate the extent of current and future shading for any proposed collector location using typical sun path calculators or similar methods ● Assure structural integrity and suitability of collector site. Test soil conditions and integrity for footing design and pipe path. (Local codes or site conditions might then require involving an engineer). ● Determine suitable location for installing all subsystem components (This includes piping, water heater, valves, and ancillary equipment required for complete system installation.) ● Practice all personnel safety requirements ● Identify any other constraints and options for the installation related to local and state code requirements ● Verify that system to be installed is appropriate for the building and climate ● Verify with the homeowner the proposed location of the collector and other major components ● Actively listens to homeowners, business owners and fellow employees to successfully install a solar thermal system. (VOG-Communicator) |
| <p>Link to Proficiency Scale</p> | |
| <p>Tiered Vocab- Plumbing and Heating students build a professional vocabulary, we have broken down the</p> | |

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CTECS Plumbing, Heating & Cooling

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) |
|--|--|--|
| Tier 1 (Everyday): <ul style="list-style-type: none"> ● Math ● Map ● Total ● Width ● Fraction | Tier 2 (Academic): <ul style="list-style-type: none"> ● Calculate ● Scale ● Proportion ● Dimension ● Accuracy | Tier 3 (Technical/Trade): <ul style="list-style-type: none"> ● Offset ● Isometric Drawing ● Center-to-Center (C-C) ● Rough-in ● O.D. vs. I.D. (Outside vs. Inside Diameter) |

Trade Math Crossover: **(VOG- Critical Thinker)**

Focus: Pipe offsets, measurements, and fractions.

1. 45-Degree Pipe Offsets:

Using the standard 1.414 multiplier for a 45-degree offset: If two parallel pipes need to be connected with an offset that has a "rise" (center-to-center distance) of 10 inches, calculate the "travel" (the diagonal length of the pipe).

2. Fitting Allowance & Cut Lengths:

A plumber is measuring for a "Center-to-Center" (C-C) distance of 24 inches between two 90-degree elbows. If the "fitting allowance" (the distance from the center of the fitting to the end of the pipe inside the hub) for each elbow is $1\frac{1}{4}$ inches, calculate the exact length the pipe needs to be cut.

3. Fractional Subtraction:

A blueprint shows a total wall length of $12\frac{3}{8}$ feet. A vanity takes up $3\frac{3}{4}$ feet and a toilet requires a $1\frac{1}{2}$ foot clearance. Calculate the remaining space on the wall in inches.

Resources to compliment learning-

- Modern Plumbing Textbook (chapter 4)
- Mathematics for Plumbers and Pipefitters (unit 19)
- Print Reading for Construction

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Crossover to Apprenticeship Standards:

- A0014 Plumbing Math

VOG Portfolio Collection Examples:

VOG-Critical Thinker

- **Example:** Students will create a rubric for setting a water closet and evaluate classmate's installation practices. Applies unbiased analysis and evaluation.

VOG Trait: A Critical Thinker

- **Example:** When given a residential floor plan, the student accurately calculates the total linear footage of pipe required and identifies potential "conflicts" where plumbing lines might interfere with structural beams or electrical runs shown on the print

VOG Trait: A Problem Solver

- **Example:** A student uses a Solar Thermal Site Assessment tool to determine the optimal placement for a collector, factoring in shading from nearby trees and roof orientation to maximize energy efficiency.

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

| Priority Standard 9.4 - Plumbing & Mechanical codes | |
|--|---|
| Big Idea(s): | |
| <ol style="list-style-type: none"> Code books govern the minimum requirements of the plumbing and heating trade necessary to protect the health of the nation. Codes and reference materials are the "law" of the trade, ensuring systems are safe and functional for residential use. | |
| Essential Question(s): | |
| <ol style="list-style-type: none"> How can plumbing and mechanical codes guide decision-making during installation and inspection? | |
| Learning Outcomes | |
| <i>Students will know:</i> | <i>As evidenced by: (oral, written, or performance)</i> |
| <ol style="list-style-type: none"> Codes and practices <ul style="list-style-type: none"> ADA IPC IMC IRC IBC IFGC IECC NFPA NABCEP | <ul style="list-style-type: none"> Identify the various codebooks, governing bodies and accepted practices the beginning plumber should follow. Define key terms a plumber uses in by trade. Explain where to find answers and information he/she will require as a plumber. Codebooks, websites etc. List the international codes their applications Possess the knowledge and skills for industry areas. (VOG: Work Ready) |
| <ol style="list-style-type: none"> Materials and various piping arrangements <ul style="list-style-type: none"> Threading Soldering Solvent cementing Copper Steel Plastics PEX Fusion | <ul style="list-style-type: none"> List, discuss and identify various materials a plumber would use in the scope of his or her duties Practice proper piping arrangements and testing procedures a plumber might use in the scope of his duties. Project sheets/mockups/shop floor. Practices outside of the box thinking. {VOG: A Problem Solver} |

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

[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) |
|--|---|--|
| <ul style="list-style-type: none"> • Rules • Safety • Space • Size • Air • Slant • Overlap • Check | <ul style="list-style-type: none"> • Standard • Mandatory • Clearance • Capacity • Ventilation • Gradient • Conflict • Inspection | <ul style="list-style-type: none"> • International Plumbing Code (IPC) • Minimum Requirements • Rough-in Dimensions • Fixture Unit (DFU/WSFU) • Back-Vent / Circuit Vent • Pitch / Slope • Cross-Connection • Hydrostatic Test |

Trade Math Crossover: **(VOG- Critical Thinker)**

Focus: Code-required clearances and area calculations.

1. **Fixture Clearance Math:** According to code, a standard water closet (toilet) requires a minimum of 15 inches of clearance from its center to any side wall. If a bathroom is 65 inches wide and a plumber wants to center the toilet exactly in the middle of that space, how many inches will there be from the center of the toilet to each side wall? Is this installation code-compliant?
2. **Drainage Grade (Pitch):** Code requires horizontal drainage piping to be pitched at $\frac{1}{4}$ inch per foot to ensure proper flow. If a waste line must run 18 feet from a sink to the main stack, calculate the total "drop" (vertical change in height) required for the pipe run.

Resources to compliment learning-

- Modern Plumbing Textbook (chapter 4)
- Mathematics for Plumbers and Pipefitters (unit 19)
- International Plumbing Code Book

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

- www.UPCODES.com

Crossover to Apprenticeship Standards:

- A0711 Plumbing Code 1
- A0741 Plumbing Code 2

VOG Portfolio Collection Examples:

VOG-Critical Thinker

- Students will have the ability to recite dimensions required by the IPC to properly rough in a ½ bath. Makes rational decisions based on application of evidence and observation.

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CTECS Plumbing, Heating & Cooling

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| <p>Priority Standard 9.5 - The proper use of the basic hand tools used In the Plumbing, Heating & Cooling Industry.</p> | |
| <p>Big Idea(s):</p> <ol style="list-style-type: none"> 1. Proper tool selection and maintenance are foundational to mechanical craftsmanship | |
| <p>Essential Question(s):</p> <ol style="list-style-type: none"> 1. How does purchasing the proper hand tools affect your daily performance? 2. How does proper maintenance of tools promote safety? | |
| <p>Learning Outcomes</p> | |
| <p><i>Students will know:</i></p> | <p><i>As evidenced by: (oral, written, or performance)</i></p> |
| <p>1. Hand tools</p> <ul style="list-style-type: none"> ● Hammers ● Wrenches ● Screwdrivers ● Threaders ● Pipe cutters ● Saws ● Pliers ● Care for tools/store tools | <ul style="list-style-type: none"> ● Model hand tool demonstration and practice proper user techniques of various hand tools. ● Demonstrate safe and proper use of required tools and equipment used in the solar trades, (Reference NABCEP 1.2) ● List sources for the purchase of hand tools. ● Explain the need for purchasing "trade quality" tools. ● Demonstrate ways in which we should care for tools/store Tools ● Possesses the knowledge and skills for industry area. {VOG: Work Ready} |
| <p>Link to Proficiency Scale</p> | |
| <p>Tiered Vocab- Plumbing and Heating students build a professional vocabulary, we have broken down the terms into three tiers based on the standard educational model:</p> <ul style="list-style-type: none"> ● Tier 1: Common, everyday words (Basic communication). | |

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

- **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) |
|---|--|---|
| <ul style="list-style-type: none"> ● Wrench ● Saw ● Pliers ● Tape Measure ● Air ● Slant ● Overlap ● Check | <ul style="list-style-type: none"> ● Manual ● Precision ● Versatile ● Calibration ● Ventilation ● Gradient ● Conflict ● Inspection | <ul style="list-style-type: none"> ● Basin Wrench ● Tubing Cutter ● Reamer ● Torque Wrench ● Back-Vent / Circuit Vent ● Pitch / Slope ● Cross-Connection ● Hydrostatic Test |

Trade Math Crossover: **(VOG: Critical Thinker)**

1. Leverage and Torque (The Pipe Wrench)

A pipe wrench is a second-class lever. Torque is calculated by multiplying the force applied by the distance from the pivot point (Torque = Force times Distance).

- **The Scenario:** A student is trying to loosen a stubborn 2-inch galvanized pipe nipple. They apply 40 lbs. of force to the end of a 14-inch pipe wrench.
- **The Math:** Calculate the torque in foot-pounds. (Hint: Convert 14 inches to feet first: $14 / 12 = 1.17 \text{ ft}$).
- **The Challenge:** If the pipe requires 60 foot-pounds of torque to break loose, how much force (lbs.) must the student apply to the same 14-inch wrench to succeed?

2. Precision Cutting and Kerf (The Hacksaw)

When cutting a pipe with a hacksaw, the blade removes a small amount of material called the "kerf."

- **The Scenario:** A student needs four exact 6-inch pieces of brass tubing. The hacksaw blade has a kerf (thickness) of $1/16$ of an inch.
- **The Math:** If the student makes four cuts to get their four pieces, what is the total length of material "lost" to the saw blade?
- **The Precision Check:** If the student starts with a 24-inch piece of tubing and makes three cuts to get four pieces, will the final piece be exactly 6 inches long? Why or why not?

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3. The Geometry of the Tubing Cutter

A tubing cutter must travel in a perfect circle around the pipe to avoid "threading" (spiraling).

- **The Scenario:** A student is cutting a piece of 1/2-inch Type L copper pipe. The outside diameter (OD) of the pipe is exactly 0.625 inches.
- **The Math:** Calculate the circumference of the pipe ($C = \pi$ times d). This is the distance the cutting wheel travels in one complete revolution.
- **The Depth Challenge:** If the wall thickness of the pipe is 0.040 inches and each turn of the cutter handle sinks the blade 0.005 inches deeper, how many full revolutions around the pipe are required to cut completely through the wall?

4. Leveling and Slope (The Torpedo Level)

Plumbing tools are used to create "pitch" for drainage. A standard torpedo level has lines to indicate 1/8" and 1/4" slope.

- **The Scenario:** A student is using a level to install a 4-foot section of PVC pipe. The code requires a slope of 1/4 inch per foot.
- **The Math:** Calculate the total "drop" (the difference in height between the start and end of the pipe) for this 4-foot run.
- **The Verification:** If the student places the level on the pipe and the bubble is exactly halfway between the center and the 1/4" mark, what is the actual slope per foot? Example: If you have a piece of 1" copper pipe, what is the inside diameter and the outside diameter of the pipe? What is the thickness of the pipe wall?

Resources to compliment learning-

- Modern Plumbing Textbook (chapter 2 and 4)

Crossover to Apprenticeship Standards:

- A0700 Introduction to Plumbing

VOG Portfolio Collection Examples:

VOG-Critical Thinker

- Applies unbiased analysis and evaluation.

VOG Trait: Work Ready

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- **Example:** After completing a task, the student cleans, services, and returns all hand tools (such as pipe wrenches, cutters, and reamers) to their designated shop area, demonstrating the organizational skills and tool maintenance expected by a professional employer.

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Priority Standard 9.6 - Demonstration of student's proficiency in basic techniques used to join pipe.

Big Idea(s):

1. Piping systems are expected to last for decades, proper connections are essential for proper system operation and longevity
2. Proficiency in joining various types of pipes (copper, PVC, etc.) is the core physical skill of the plumbing trade.

Essential Question(s):

1. Why is it essential to use the correct assembly methods for a given material?

Learning Outcomes

Students will know:

As evidenced by: (oral, written, or performance)

1. Pipe joining methods: steel pipe, copper tubing and plastics.

- Soldering
- Flaring
- Compression
- Threading
- Solvent cementing
- Mechanical

Demonstrate those skills that define proper techniques for joining materials.

- Identify schedules/types and lengths that pipes/tubing are available in.
- **Demonstrates a strong work ethic. (VOG: Work Ready.)**

2. Cast iron pipe by incorporating clamping/bell and spigot techniques that plumbers use in their daily tasks.

- no-hub pipe
- bell and spigot

- Identify the different types of cast iron soil pipe.
- Demonstrate clamping/bell and spigot techniques.
- Explain different methods of joining cast iron soil pipe.
- Complete teacher designed instruments for feedback on learning skills. (Questions, quizzes, tests,)
- **Innovates new styles and techniques for joining piping materials (VOG: A Critical Thinker)**

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2. 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)
- Analyze the extent of, and make allowances for expansion of pipe and its effect on hangers and the integrity of the pipe.
- Determine type, length, and diameter of copper piping required
- Cut copper pipe to desired length
- Solder copper piping connections
- Test soldering fittings for leaks
- Select the type, length, and diameter of plastic piping required
- Cut plastic pipe to desired length
- Glue plastic piping connections
- Test glued fittings for leaks
- Choose the type, diameter, and length of insulation required
- Cut insulation and install over piping and plumbing fittings
- Miter insulation ends, where appropriate
- Glue and seal insulation joints, as required
- Select ultraviolet radiation protective method
- Protect insulation from ultraviolet degradation
- Determine type, length, and diameter of CSST
- piping required
- Cut CSST pipe to desired length

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|---|---|
| | <ul style="list-style-type: none"> ● Join CSST piping connections ● Test CSST Tubing & fittings for leaks |
| 3. Troubleshoots and determines problems found within a solar heating system. | <ul style="list-style-type: none"> ● Able to determine the root cause of issues. (VOG: A Problem Solver) |

[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) |
|--|---|--|
| <ul style="list-style-type: none"> ● Glue ● Pipe ● Metal ● Joint | <ul style="list-style-type: none"> ● Adhesion ● Component ● Durability ● Assembly | <ul style="list-style-type: none"> ● Solvent Weld ● PEX (Cross-linked Polyethylene) ● Flux ● Fitting (Ells, Tees, Couplings) |

Trade Math Crossover:

Focus: Material estimation and volume.

1. **Solder and Flux Estimation:** A 9th-grade shop project requires joining 12 copper fittings. If one roll of solder can complete approximately 40 joints of ½ -inch pipe, what decimal fraction of a roll will be used for this project?
2. **Pipe Volume (Basic):** To test a new section of 2-inch PVC pipe for leaks, it must be filled with water. If the pipe is 10 feet long and 1 foot of 2-inch pipe holds approximately 0.16 gallons, calculate the total gallons of water needed to fill the pipe for the test.

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3. **Measurement:** If you have a measurement of 12 inches face to face for 2- 1-inch black steel 90-degree elbows, what would be the length of your cut after you calculate the fitting allowance?
(VOG: Critical Thinker)

Resources to compliment learning-

- Modern Plumbing Textbook (chapter 9)
- International Plumbing

Crossover to Apprenticeship Standards:

- A0700 Introduction to Plumbing

VOG Portfolio Collection Examples:

VOG- Work Ready

- Students will create a 10-step set up plan for an acetylene "B" Tank and torch

VOG Trait: A Problem Solver

- **Example:** After a pressure test on a newly joined copper line reveals a pinhole leak, the student analyzes the joint, identifies if the cause was improper fluxing or insufficient heat, and successfully executes a repair.

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CONNECTICUT TECHNICAL EDUCATION
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Grade 10

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Grade 10 Curriculum

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| Priority Standard 10.1 - Safety protocols and OSHA regulations. | |
| Big Idea(s): 1. Your future depends on your health and well-being. | |
| Essential Question(s): How can little accidents cause catastrophic problems? | |
| Learning Outcomes | |
| <i>Students will know:</i> | <i>As evidenced by: (oral, written, or performance)</i> |
| 1. Safety practices <ul style="list-style-type: none"> ● Ladder Safety ● Hand and Power tool Safety ● Stationary Tool Safety | <ul style="list-style-type: none"> ● Score 100% proficiency on all safety tests or retests. ● Demonstrate safe practices while using tools and power tools. ● Wear proper safety apparatus while in shop area. ● Recite fire safety procedures ● Identify potential safety risks associated with hazardous equipment. ● Explain ladder and scaffold safety precautions. ● Explain & Demonstrate proper ladder setup and climbing techniques. ● Explain & Demonstrate knowledge of emergency cut-offs. ● Explain & demonstrate to others the knowledge of ● Lock Down, Secure the Building and Fire Escape Routes ● (VOG- An Effective Communicator) |
| 2. Ground Fault Circuit Interrupters. | <ul style="list-style-type: none"> ● Explain & demonstrate where and why GFCI are required and correct procedure for testing of GFCI. |

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| | <ul style="list-style-type: none"> ● Explain & demonstrate use of GFCI protected cords. |
| 3. Proper material handling | <ul style="list-style-type: none"> ● Correctly lift objects off the floor. ● Explain why it is necessary to use safety precautions while lifting |
| 4. O.S.H.A, and S.D.S. | <ul style="list-style-type: none"> ● Explain why we have S.D.S sheets and be able to locate upon request. ● Created an essay on OSHA & SDS ● Explain what O.S.H.A. responsibilities are, and explain why they are important. ● Interpret S.D.S. sheets. |
| 5.Safety guidelines personal health | <ul style="list-style-type: none"> ● Explain necessity for following safety protocol, while also managing personal health. |
| 6.Jobsite safety procedures | <ul style="list-style-type: none"> ● Clearly and concisely conveys information. (VOG: An Effective Communicator, Skilled Socially)) |

[Link to Proficiency Scale 9-1](#)

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| Tier 1 (Everyday) | Tier 2 (Academic) | Tier 3 (Technical/Trade) |
|--|--|---|
| <ul style="list-style-type: none"> ● Danger ● Rules ● Cleanup ● Breathing ● Falling ● Electricity ● Dirt Hole | <ul style="list-style-type: none"> ● Hazardous ● Mandatory ● Mitigation ● Respiratory ● Elevation ● Conductivity ● Excavation | <ul style="list-style-type: none"> ● OSHA 1926 (Construction Standards) ● Housekeeping / Containment ● SCBA / N95 Rating ● Fall Arrest System / PFAS ● Arc Flash / Grounding |

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|--|--|---|
| <ul style="list-style-type: none"> ● Chemicals | <ul style="list-style-type: none"> ● Toxicity | <ul style="list-style-type: none"> ● Trench Shoring / Sloping ● HCS (Hazard Communication Standard) |
| <p>Trade Math Crossover: (VOG- Problem Solver)</p> <p><i>Focus: Load calculations and safety thresholds.</i></p> <ol style="list-style-type: none"> OSHA Trenching Safety: OSHA requires that any trench 5 feet or deeper must have a protective system (shoring, shielding, or sloping). If a plumber is excavating for a new sewer line that must drop 1/4 inch per foot, and the starting depth is 48 inches at the house, calculate the exact distance (in feet) the pipe can run before the trench reaches the 60-inch (5-foot) "safety threshold" requiring a trench box. Fall Protection Math: A personal fall arrest system must be rigged so that a worker can neither free fall more than 6 feet nor contact any lower level. If a student is working on a platform 18 feet high using a 6-foot lanyard and a deceleration device that expands 3.5 feet, calculate the total "fall clearance" required (including a 3-foot safety factor). Does the 18-foot height provide enough clearance? Angle of Repose: If you have an excavation of 15 feet in depth, a bottom width of 5 feet, type A soil, and an Angle of Repose of $\frac{3}{4}$:1 ratio, Determine the width at the top of the trench. | | |
| <p>Resources to compliment learning-</p> <ul style="list-style-type: none"> ● OSHA CFR 1926, ● Modern Plumbing Textbook Chapter 1 | | |
| <p>Crossover to Apprenticeship Standards:</p> <ul style="list-style-type: none"> ● A0099 Building Trades Safety OSHA 30 for construction certification | | |
| <p>VOG Portfolio Collection Examples:</p> <p>VOG- Critical Thinker</p> <ul style="list-style-type: none"> ● Students will develop a basic shop safety plan for daily safety expectations and routines. | | |

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Priority Standard 10.2 - Proper installation practices of common piping systems

Big Idea(s):

1. Modern Plumbing, Heating & Cooling systems must be designed and installed properly to ensure longevity.

Essential Question(s):

How do installation practices impact the performance of modern Plumbing, Heating & Cooling systems?
 What factors do you need to know to insure a high-quality piping installation?

Learning Outcomes

| <i>Students will know:</i> | <i>As evidenced by: (oral, written, or performance)</i> |
|---|---|
| 1. Copper Tube <ul style="list-style-type: none"> ● Types (identified as colors) ● Lengths ● Drawn, Annealed ● Uses ● Joining methods (Including Minimum Testing Requirements) ● Wrought and cast (fittings) ● Hanger types and spacing ● Advantages and disadvantages | <ul style="list-style-type: none"> ● Demonstrates knowledge of copper tubing types and uses |
| 2. Steel Pipe <ul style="list-style-type: none"> ● Schedule ● Galvanize ● Joining methods (including Minimum Testing Requirements) ● Fittings ● Hanger types and spacing ● Malleable and cast iron ● Roll grooved flange type ● Advantages and disadvantages | <ul style="list-style-type: none"> ● Demonstrates knowledge of steel piping types and uses. |
| 3. Plastic Pipe <ul style="list-style-type: none"> ● Schedules, types ● Joining methods (including Minimum Testing Requirements) | <ul style="list-style-type: none"> ● Demonstrates knowledge of plastic types of piping materials. |

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| <ul style="list-style-type: none"> ● Fittings ● Hanger types and spacing ● Advantages and disadvantages | |
| <p>4. Cast Iron Pipe</p> <ul style="list-style-type: none"> ● Types ● Lengths ● Joining methods (including minimum testing requirements) ● Fittings ● Hanger types and spacing ● Advantages and disadvantages | <ul style="list-style-type: none"> ● Demonstrates knowledge of cast iron piping types and uses. |
| <p>4. Fitting Allowance Calculations</p> | <ul style="list-style-type: none"> ● Demonstrates Face-to-Face, Center-to-Center, and other various fitting calculations. ● Practices creative outside the box thinking- (VOG- A problem Solver) |
| <p>5. Solar Thermal Piping: (Reference: NABCEP 7.16-7.26)</p> <ul style="list-style-type: none"> ● Flashing ● Penetrations ● Sealants ● Slope Strategy ● Hangers ● Standoffs ● Connection ● Underground Piping Methods ● Connection of components | <ul style="list-style-type: none"> ● (Reference: NABCEP7.16-7.26) ● Determine type of pipe flashing to use for specific roof type ● Determine the area where pipe flashing will be installed ● Make roof penetrations ● Install pipe flashing and sealant ● Determine slope strategy of piping to avoid traps on horizontal runs ● Slope piping to avoid traps in horizontal pipe runs ● Attach pipe hangers and supports ● Install stand-off hangers beneath piping on roof if needed ● Connect all system piping to the water heater tank, collector, valves, pumps, etc. ● Determine underground piping method ● Install underground piping |
| <p>Link to Proficiency Scale</p> | |

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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) |
|--|---|--|
| <ul style="list-style-type: none"> • Straight • Hang • Space • Expansion • Rubbing • Digging • Tight • Passing through | <ul style="list-style-type: none"> • Vertical / Horizontal • Suspension • Interval • Thermal Movement • Abrasion • Excavation • Compression • Penetration | <ul style="list-style-type: none"> • Plumb and Level • Clevis Hanger / Split Ring • Support Spacing (per Foot) • Expansion Loop / Offset • Dielectric Union / Isolator • Bedding and Backfilling • Torque Specifications • Firestopping / Sleeving |

Trade Math Crossover: **(VOG- Critical Thinker)**

Focus: Fitting allowances and material efficiency.

1. **PVC Fitting Allowance:** You are installing a 2-inch PVC drain line. The center-to-center (C-C) measurement between two 90-degree elbows is 18 inches. If the fitting allowance (the distance from the center of the 90-degree elbow to the internal stop of the hub) is $2 \frac{3}{16}$ inches for each fitting, calculate the precise "cut length" of the pipe needed to ensure a tight fit.
2. **Steel Pipe Threading:** When working with 1-inch threaded steel pipe, the "thread engagement" (the distance the pipe screws into the fitting) is approximately $\frac{11}{16}$ of an inch. If you need a face-to-face finished length of 32 inches between two threaded tees, how long must your piece of pipe be before threading?
3. **Fitting Allowance:** If you have two 2" PVC 90-degree elbows with a face-to-face measurement of 12 inches, what would be the measurement for the cut piece of pipe needed?

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Resources to compliment learning-

- Modern Plumbing Textbook (chapter 4)
- Mathematics for Plumbers and Pipefitters (unit 8)

Crossover to Apprenticeship Standards:

- A0014 Plumbing Math

VOG Portfolio Collection Examples:

VOG- Problem Solver

- Students will calculate pipe travel using fitting allowance charts from various fitting manufacturers.

VOG Trait: A Problem Solver

- **Example:** When installing a drainage run, a student encounters a structural obstacle not shown on the original plan. They apply "outside the box thinking" to recalculate the fitting allowance and adjust the pipe's path while maintaining the required 1/4" per foot slope.

VOG Trait: A Critical Thinker

- **Example:** Before making a cut, a student calculates the "Face-to-Face" and "Center-to-Center" measurements for a 2" PVC assembly, verifying their math against the physical fittings to ensure a leak-proof, high-quality installation.

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| Priority Standard 10.3 - Plumbing Math and Science. | |
|--|--|
| Big Idea(s): 1. Plumbing, Heating & Cooling systems rely on design calculations based on math and science to function properly. | |
| Essential Question(s): 1. What are some ways that math and science are used in the Plumbing, Heating & Cooling trade? | |
| Learning Outcomes | |
| <i>Students will know:</i> | <i>As evidenced by: (oral, written, or performance)</i> |
| 1. Related math: <ul style="list-style-type: none"> ● scale ● rulers ● decimal ● fractions ● decimals to fraction, fraction to decimals ● circles ● angles ● percentage ● Convert inches to feet, feet to inches ● Calculate mixed numbers ● Calculate offsets. ● Calculate area (Circle, square footage) ● Water pressure, Volume. | <ul style="list-style-type: none"> ● Explain and demonstrate trade related math and science. ● Demonstrates knowledge of converting inches to feet and feet to inches: ● Calculating mixed numbers to add total lengths of piping ● Calculating maximum quantity of pipes that can be cut from a master length. ● Calculating offsets. ● Calculated area of a circle, square footage, volume, and water pressure. ● Applies unbiased analysis and evaluation (VOG-A Critical Thinker) |
| 2. Properties of: <ul style="list-style-type: none"> ● Waste products. ● Water and its sources. ● Various gases. ● Waste disposal. ● Trap seal loss, ex: siphonage, aspiration, momentum, back pressure, evaporation & capillary action. | <ul style="list-style-type: none"> ● Demonstrates knowledge of trade related science. ● Demonstrates knowledge of dangers of waste products. ● Explains properties of water and its sources. ● Designated properties of various gasses. ● Described methods of waste disposal. ● Demonstrates Trap seal loss, ex: siphonage, aspiration, momentum, back pressure, evaporation & capillary action. |

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[Link to Proficiency Scale](#)

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| Tier 1 (Everyday) | Tier 2 (Academic) | Tier 3 (Technical/Trade) |
|---|---|---|
| <ul style="list-style-type: none"> • Weight • Push • Falling Water • Taking up Space • Diagonal • Expanding • Sucking • Turning | <ul style="list-style-type: none"> • Mass / Density • Force / Resistance • Elevation Loss • Volume • Hypotenuse • Thermal Expansion • Vacuum • Mechanical Advantage | <ul style="list-style-type: none"> • Specific Gravity • PSI (Pounds per Square Inch) • Head Pressure • Cubic Capacities • Travel / Offset • Coefficient of Expansion • Siphonage / Backflow • Torque / Leverage |

Trade Math Crossover: **(VOG- Critical Thinker)**

Focus: Pressure, head, and volume.

1. **Hydrostatic Pressure Calculations:** Water exerts a pressure of 0.433 psi for every foot of vertical "head" (height). If a building has a roof-mounted water storage tank 80 feet above the ground floor, calculate the static water pressure (psi) available at a faucet on the first floor.
2. **Volume and Weight:** A 40-gallon water heater is being installed on a second-floor shelf. If water weighs 8.34 lbs. per gallon and the empty water heater weighs 95 lbs., calculate the total weight the shelf must support when the tank is full.
3. **Expansion Calculations:** Copper pipe expands at a rate of 1.1 inches per 100 feet for every 100-degree Fahrenheit rise in temperature. If a hot water main is 60 feet long and the water temperature increases from 50°F to 150°F, calculate the total linear expansion in inches.

Area/Volume: If you have a water heater with no identification on it and is 24 inches in diameter

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and 50 inches tall, calculate the capacity of the water heater.

Resources to compliment learning-

- Modern Plumbing Textbook (chapter 4)
- Mathematics for Plumbers and Pipefitters (unit 19)

Crossover to Apprenticeship Standards:

- A0014 Plumbing Math

VOG Portfolio Collection Examples:

VOG- Problem Solver

- **Students will determine the size of a water heater that has no markings to install the proper size.**

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Priority Standard 10.4 - Introduction to Pumping Systems.

Big Idea(s):

1. Fluids can be manipulated by several types of pumping systems.
2. Pumping systems are essential for the efficient movement of fluids in modern residential and commercial settings.

Essential Question(s):

How can we transfer fluids to make them work to our advantage? {VOG- A Critical Thinker}

Learning Outcomes

Students will know:

As evidenced by: (oral, written, or performance)

1. Pump types:

- **Well pumping systems (One pipe jet pump, two pipe jet pump, Submersible pump)**
- **Constant Pressure Systems**
- Booster pump
- **Sewage pump**
- **Dewatering pump (sump).**
- Transfer pumps
- **Oil Burner pumps, single and dual stage**
- **Solar Thermal Circulating Pumps**
(Reference NABCEP 8.6, 8.7, 9.3)

- Knowledge of proper use and physical differences of various pumping systems.
- Describe the use of the following: one and two pipe jet pump, submersible pump, booster pump, sewage pump, dewatering pump.
- **Demonstrate installation practices for constant pressure well systems. (VOG- Work Ready: Possess knowledge and skills for industry area)**
- Describe the proper equipment necessary for each well application (tanks, accessories, etc.).
- Size pump equipment and accessories based on manufacturers specifications for specific applications.
- (Reference NABCEP 8.6, 8.7, 9.3)
Determine pump location for solar thermal installations
- Install the solar thermal pump according to the manufacturer's installation manual

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| | <ul style="list-style-type: none"> ● Install photovoltaic module controller and pump |
| <p>2. Types of wells and Well Equipment</p> <ul style="list-style-type: none"> ● Types of wells ● Tanks ● Pump switches ● Pump accessories | <ul style="list-style-type: none"> ● Differentiate types of wells and methods of digging and drilling. ● Describe how well sources are located. ● Determine the GPH of a well ● Demonstrate how to calculate well recovery and drawdown ● Demonstrate knowledge of pump controls. |
| <p>3.Types of well pumps</p> <ul style="list-style-type: none"> ● Jet ● Submersible ● Sewage pumps | <ul style="list-style-type: none"> ● Identify physical differences between jet, submersible, and sewage pumps and equipment. |
| <p>4. Electrical testing instruments.</p> <ul style="list-style-type: none"> ● Electrical Control Systems as it pertains to Solar Thermal Systems (Reference NABCEP 9.1, 9.2, 9.4, 9.8) | <ul style="list-style-type: none"> ● Demonstrate knowledge of basic electricity. ● (Reference NABCEP 9.1, 9.2, 9.4-9.8) ● Determine the location of the controller ● Install differential controller and sensors ● Install a timer controller ● Install control wiring ● Select ultraviolet radiation protective method for external wiring ● Protect external wiring from ultraviolet degradation ● Test operation of controller |
| <p>5. Water Supply Systems</p> <ul style="list-style-type: none"> ● Design methods ● Pipe sizing ● Water Treatment ● Installation Methods ● Supply piping testing procedures | <ul style="list-style-type: none"> ● Classify the different styles of water supply systems ● Size a residential water distribution system ● Explain different types of water filtration and treatment systems ● Layout and design of a residential water distribution system |

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[Link to Proficiency Scale](#)

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| Tier 1 (Everyday) | Tier 2 (Academic) | Tier 3 (Technical/Trade) |
|--|--|---|
| <ul style="list-style-type: none"> • Pump • Suction • Spinning Part • Back-up • Pushing Power • One-way Valve • Float • Air Lock | <ul style="list-style-type: none"> • Circulation • Intake / Vacuum • Component • Redundancy • Efficiency • Prevention • Activation • Obstruction | <ul style="list-style-type: none"> • Centrifugal Pump • NPSH (Net Positive Suction Head) • Impeller • Duplex System • Total Dynamic Head (TDH) • Check Valve / Backwater Valve • Mechanical Float Switch • Cavitation |

Trade Math Crossover:

Focus: Pump curves, flow rates, and head pressure.

1. **Reading a Pump Curve:** A circulator pump must move water through a secondary heating loop that has a calculated "Total Dynamic Head" (resistance) of 12 feet. Using a manufacturer's pump curve (Performance Map), if the pump is set to Speed 2 and provides 8 Gallons Per Minute (GPM) at 10 feet of head, but only 4 GPM at 14 feet of head, use linear interpolation to estimate the GPM the pump will deliver at exactly 12 feet of head.
2. **Sizing a Sump Pump:** A basement sump pit is 24 inches in diameter and 30 inches deep. To prevent flooding during a storm, the pump must be able to empty the pit in 90 seconds.

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- **Step A:** Calculate the volume of the pit in cubic inches ($V = \pi r^2 h$).
 - **Step B:** Convert that volume to gallons (231 cubic inches = 1 gallon).
 - **Step C:** Determine the minimum GPM rating the pump must have to meet the 90-second requirement.
3. **Static Head vs. Total Head:** A pump is lifting water from a storage tank in the basement to a fixture on the third floor, a vertical distance of 32 feet. If the friction loss in the pipes adds an additional 5 feet of "resistance head," calculate the total pressure in PSI the pump must generate to just break even (1 foot of head = 0.433 PSI)
4. **Volume/Pressure:** Example: If you have a well line that is 100 feet in length, 1 inch in diameter and is full of water, calculate the head pressure for that line.

Resources to compliment learning-

- Modern Plumbing Textbook (chapter 4 & 11)
- Mathematics for Plumbers and Pipefitters (unit 47)
- International Plumbing Code Book (section 6)
- www.pumps.org

Crossover to Apprenticeship Standards:

- A0014 Plumbing Math
- A0750 Wells Pumps and Piping 1
- A0751 Wells Pumps and Piping 2

VOG Portfolio Collection Examples:

VOG- Work Ready

- **Students will determine well capacities and fixture demands to properly size a well pump.**

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Priority Standard 10.5 - Residential Fixtures, Appliances, and Solar Thermal.

Big Idea(s):

1. Standard and ADA layouts have very different rules for health and accessibility
2. Fixtures and Appliances contribute to our health and wellbeing in everyday life

Essential Question(s):

1. **How do plumbing fixtures and appliances impact our daily lives? (VOG-A Critical Thinker)**

Learning Outcomes

Students will know:

As evidenced by: (oral, written, or performance)

1. Fixtures

- Types of fixtures and designs
- ADA Compliant
- Standard

- **Demonstrated knowledge and application of fixtures and appliances including water heaters.**
- **Explain where and why fixtures are required.**
- Explain & demonstrate correct procedure for testing of fixtures and appliances
- Installation Methods

2. Appliances

- Water heaters
- Boilers
- clearance codes
- Water conservation
- Safety valves & Controls

- Identify and Install Appliances
- Apply Applicable code regulations
- Apply minimum fixture installation clearances
- **Describe importance of safety valves and controls**
- **Compare & Contrast High-Efficiency appliances versus non-HE Appliances (VOG-Critical Thinker)**
- **Explain where and why fixtures are required.**
- **Explain & demonstrate correct procedure for testing of fixtures and appliances (VOG-Critical Thinker)**
- Identify and Apply Water conservation requirements.

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| | <ul style="list-style-type: none"> ● Safety requirements for fixtures and appliances (tempering valves, T&P relief valves, backflow preventers etc.). |
| <p>3. Solar Thermal Systems and their components Reference (NABCEP 2.1-2.5)</p> <ul style="list-style-type: none"> ● Active ● Passive ● Indirect ● Swimming Pool | <ul style="list-style-type: none"> ● Reference Solar Thermal Systems and their components Reference (NABCEP 2.1-2.5) ● Identify components specific to an active direct solar system including: collector, tank, pump, controller, sensors, isolation and drain valves, pressure and temperature relief valves, air vent, piping, insulation, flashing, etc. This would apply to the components relevant to each specific type of system. ● Identify components specific to an active indirect solar system ● Identify components specific to a passive direct solar System ● Identify components specific to a passive indirect solar system ● Identify components specific to a swimming pool heating solar system |
| <p>4. Solar Hot Water Heaters and Storage Tanks. (Reference NABCEP 6.1-6.18)</p> <ul style="list-style-type: none"> ● Environmental ● Inspection ● Piping strategy ● Retrofit installation ● Auxiliary storage ● System fills and start-up procedures | <p>(Reference NABCEP 6.1-6.18)</p> <ul style="list-style-type: none"> ● Prepare the environment for tank installation (water and power source) ● Determine by inspection that the new water heater and/or storage tank and required subcomponents are damage free ● Determine tank ports to be used for plumbing lines ● Determine dip tube strategy ● Determine plumbing retrofit method to be used if conventional water heater tank (electric or gas) is used |

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| | <ul style="list-style-type: none"> ● Install drain pan per local codes ● Remove the old conventional water heater tank, if required ● Install dip tubes ● Install port fittings if required ● Install tank valves (drain, pressure temperature relief, etc.) ● Connect plumbing and valves between solar tank ● and conventional auxiliary tank (if required) ● Connect water heater and/or storage tank to water source ● Fill tank with water ● Connect the water heater and/or storage tank to power source ● Determine that water heater and storage tanks are installed per manufacturer's' recommendations and code ● Determine that installed tank and fittings have no leaks |
|--|--|

[Link to Proficiency Scale](#)

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| Tier 1 (Everyday) | Tier 2 (Academic) | Tier 3 (Technical/Trade) |
|--|---|--|
| <ul style="list-style-type: none"> ● Sewer Gas ● Hot Water ● Sun Power ● Panel | <ul style="list-style-type: none"> ● Protection ● Domestic Supply ● Renewable Energy ● Collection | <ul style="list-style-type: none"> ● P-Trap / Water Seal ● Solar Storage Tank ● Photovoltaic (PV) vs. Thermal |

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|--|---|---|
| <ul style="list-style-type: none"> ● Liquid ● Dishwasher ● Water Saver ● Glass | <ul style="list-style-type: none"> ● Transfer Medium ● Appliance ● Conservation ● Glazing | <ul style="list-style-type: none"> ● Flat-Plate / Evacuated Tube ● Glycol / Heat Transfer Fluid ● Air Gap / High Loop ● Low-Flow / Water-Sense ● Selective Surface Coating |
|--|---|---|

Trade Math Crossover:

Focus: ADA clearances and rough-in dimensions.

1. **ADA Turning Radius:** ADA code requires a 60-inch diameter clear turning space in a bathroom for wheelchair accessibility. If a small bathroom is 5 feet 6 inches wide by 8 feet long, and a vanity depth is 22 inches, calculate the remaining width of the floor. Does this remaining space meet the 60-inch (5-foot) diameter requirement?
2. **Water Closet Rough-In:** A standard water closet has a "rough-in" dimension (distance from the finished wall to the center of the drain) of 12 inches. If the framed wall is currently bare studs and you will be adding 1/2-inch cement board and 3/8-inch-thick tile, what is the exact distance the center of the drain should be placed from the *raw stud* to ensure a perfect 12-inch finished rough-in?
3. **Water Closet Rough-In:** Determine the rough in dimensions of a standard water closet from a fixture rough-in sheet and the International Plumbing Code.

Resources to compliment learning-

- Modern Plumbing Textbook Chapter 13 and Chapter 17
- International Plumbing Code Chapter 4
- <https://up.codes/building-codes-online>
- <https://codes.iccsafe.org/>

Crossover to Apprenticeship Standards:

- A0708 Fixtures and Appliances
- A0711 Plumbing Code 1

VOG Portfolio Collection Examples:

VOG- Work Ready:

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- Students will extract information from rough in sheets and blue prints for a standard half- bath rough.

VOG Trait: A Critical Thinker

- **Example:** Using an AI-embedded project, a student acts as a "Code Inspector" to verify if a bathroom layout meets **ADA (Americans with Disabilities Act)** standards. They mark out the floor in the shop to physically test if a wheelchair has the required turning radius based on their research.

VOG Trait: Work Ready

- **Example:** A student extracts specific information from a manufacturer's "rough-in sheet" to accurately position the water and waste lines for a standard half-bath, demonstrating the industry-specific technical literacy required for the workforce.

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Priority Standard 10.6- Employer expectations

Big Idea(s):

- Quality employees are the backbone to an organization; there are many attributes that encompass a good employee; personal attributes are as important as technical expertise**

Essential Question(s):

How are personal attributes as important as technical expertise?
 What is the relationship between organization and productivity?

Learning Outcomes

Students will know:

As evidenced by: (oral, written, or performance)

1. Customer and employer expectations on the job site:

- Time on task
- Organizational skills
- Conflict resolution
- Teamwork
- Personal appearance
- Safe work habits
- Appropriate workplace language
- Proper written expression

- Explains the importance of being punctual, considerate, organized, well-groomed, respectful, neat, team-player, and even tempered
- Explains the need for keeping truck and tools organized
- Explains teamwork and the need for it. (VOG- An effective communicator)
- Contributes new ideas when working on a project.
- Collaborate with fellow co-workers and offer assistance when needed.
- Works well in resolving conflict within an organization.
- Write detailed paper describing why needless conversation creates an uneasy feeling between customers and employees
- Explains why using proper procedures are essential in the trade
- Explains why it is essential to keep

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| | growing in the trade | |
| <p>2. Organizational skills required to be successful in the trade areas</p> <ul style="list-style-type: none"> ● making material lists, ● organizing tools, ● notebook, ● creation of job sheets, ● man-hours taken to do tasks ● materials required to complete tasks | <ul style="list-style-type: none"> ● Using student created material list complete proscribed project to industry standards ● Cleans, services and returns tools and equipment to designated shop area as required by shop policies ● Produce organized shop notebook in accordance with rubric ● Produce customer acceptable job sheets for ongoing projects which include man hours and material sheets for instructor grading by rubric. | |
| <p>3. Job applications & mock interview.</p> | <ul style="list-style-type: none"> ● Filled out mock applications and conducted mock interview. | |
| <p>4. Technology solutions</p> | <ul style="list-style-type: none"> ● Selects and safely uses technological resources to accomplish work responsibilities in a productive manner. ● Uses computers, file management techniques and software programs effectively. | |
| <p><u>Link to Proficiency Scale</u></p> | | |
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| Tier 1 (Everyday) | Tier 2 (Academic) | Tier 3 (Technical/Trade) |

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| <ul style="list-style-type: none"> ● On time ● Clean clothes ● Talking ● Hard work ● Nice ● Helping others ● Doing it right ● Learning | <ul style="list-style-type: none"> ● Punctuality ● Professionalism ● Communication ● Work Ethic ● Courtesy ● Collaboration ● Accountability ● Adaptability | <ul style="list-style-type: none"> ● Reliability / Shift Adherence ● Standard Operating Procedure (SOP) ● Active Listening / Soft Skills ● Productivity / Billable Hours ● Customer Relations Management (CRM) ● Team Dynamics / Interpersonal Skills ● Quality Assurance (QA) ● Continuous Improvement / Lifelong Learning |
|--|--|---|

Trade Math Crossover: [\(VOG: Problem Solver\)](#)

Focus: Labor costs, material markups, and project management.

1. **Labor Burdens and Profitability:** An employer charges a customer \$110 per hour for a 10th-grade apprentice's labor. The apprentice is paid \$18 per hour, but the employer also pays 25% in "labor burden" (taxes, insurance, and benefits). If a water heater installation takes 4.5 hours, calculate the **gross profit** the company makes on labor after paying the apprentice's total costs.
2. **The "Take-Off" and Material Markup:** A student is tasked with creating a material list for a bathroom rough-in. The total cost of materials (PVC, glue, hangers) from the supply house is \$415.60. The company policy is to apply a 30% "markup" to all materials. Calculate the final price the customer will be billed for these materials.
3. **Time Management and Efficiency:** A plumbing firm estimates that a standard residential "stack" takes 8 man-hours to complete. If a lead journeyman and a 10th-grade apprentice work together, and the apprentice works at 60% of the speed of the journeyman, calculate how many clock hours it will take the two-person team to complete the task.

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4. **Tool Inventory Depreciation:** A contractor purchases a new \$1,200 press tool for the shop. If the tool loses 20% of its value every year (depreciation), calculate the tool's remaining value after the student completes their 10th and 11th-grade years (2 years total)
5. **Apprentice to Licensed Plumber ratio:** If a company has 4 apprentices, how many licensed plumbers do they need to have?

Resources to compliment learning-

- Modern Plumbing Textbook (chapter 32)
- CTECS Licensed Trades VOG Resources

Crossover to Apprenticeship Standards:

- A0700 Introduction to Plumbing

VOG Portfolio Collection Examples:

VOG: An Effective Communicator

- Students will conduct a mock interview as a candidate and as an employer.

VOG Trait: An Effective Communicator

- **Example:** During a group project, a student takes the lead in "circling up" for peer feedback. They clearly explain their installation choices to their teammates and listen to suggestions to resolve conflicts and improve the team's efficiency.

VOG Trait: Work Ready

- **Example:** The student maintains a professional shop notebook and digital portfolio, documenting each project with photos and technical reflections. They consistently clean and service their tools after use, treating the school shop like a professional job site.

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| Priority Standard 10-7 - Plumbing, Heating & Cooling Blue Print Reading | |
|---|---|
| <p>Big Idea(s):</p> <p>1. Blueprints are concepts on paper that give objects dimensions and shapes.</p> | |
| <p>Essential Question(s):</p> <p>1. How does blueprint reading help turn an abstract concept into a concrete object?</p> <p>2. What kinds of information are available to you from a blueprint?</p> | |
| Learning Outcomes | |
| <i>Students will know:</i> | <i>As evidenced by: (oral, written, or performance)</i> |
| <p>1. Basic blueprint skills.</p> <ul style="list-style-type: none"> ● Symbols ● Scale ● Rough in sheets and single line drawings ● Transfer information from blueprint to mechanical drawing ● Orthographic and isometric drawings | <ul style="list-style-type: none"> ● Demonstrate skills that define proper blueprint interpretation ● Complete instructor driven project using the architect scale ● Reference rough in sheet to properly lay out specific plumbing task ● Create various scale drawings of residential installation using appropriate tools and techniques in accordance with industry standards ● Use and application of orthographic and isometric drawings ● Complete proficiency assessment on plumbing symbols on blueprints ● Extract information from prints or drawings and apply them to practical work |
| <p>Link to Proficiency Scale</p> | |
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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) |
|---|---|---|
| <ul style="list-style-type: none"> ● Drawing ● Signs ● Top View ● Side View ● Size ● Labels ● Change ● Measurements | <ul style="list-style-type: none"> ● Illustration ● Symbols ● Perspective ● Elevation ● Proportion ● Specifications ● Modification ● Dimensions | <ul style="list-style-type: none"> ● Schematic / Isometric Projection ● Legend / Abbreviations ● Plan View ● Section View / Detail ● Scale (e.g., 1/4" = 1') ● Schedules (Fixture/Pipe) ● Addendum / RFI (Request for Info) ● Center-to-Center / Rough-in |

Trade Math Crossover: **(VOG: Critical Thinker)**

Focus: Scaling and material take-offs.

1. **Architectural Scaling:** A blueprint is drawn to a scale of 1/4" = 1'-0". Using a ruler, a plumber measures a run of pipe on the drawing at 5 3/4 inches long. Calculate the actual real-world length of the pipe that needs to be ordered.
2. **Fixture Spacing Math:** A commercial restroom blueprint shows a wall 15 feet long with four identical sinks to be installed with equal spacing between them and equal spacing from the end walls. If each sink is 20 inches wide, calculate the exact measurement (in inches) that should be between each sink.
3. **Scale:** Students will create a chalk line outline of a full-size bathroom on the floor or ground from a scaled drawing.

Resources to compliment learning-

- Modern Plumbing Textbook (chapter 6)
- International Plumbing (section 4)
- <https://up.codes/building-codes-online>
- <https://codes.iccsafe.org/>

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- Print Reading for Construction

Crossover to Apprenticeship Standards:

- A0700 Intro to Plumbing
- A0031 Basic Blueprint Reading

VOG Portfolio Collection Examples:

VOG- A Critical Thinker

- Students will create an Isometric drawing of a residential 2 bath floor plan.

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Priority Standard 10-8 - Repair and service of residential Plumbing, Heating & Solar Thermal Systems.

Big Idea(s):

1. Plumbing, Heating & Solar Thermal systems require maintenance and qualified technicians to service them.

Essential Question(s):

1. **How would you calculate the typical expenses for a service call?**

Learning Outcomes

| <i>Students will know:</i> | <i>As evidenced by: (oral, written, or performance)</i> |
|---|---|
| <p>1. Troubleshooting and repair</p> | <ul style="list-style-type: none"> ● Identifies when to repair or replace equipment. ● Repairs/replaces various faucets and fixtures and appliances. ● Repairs/replaces domestic water heating equipment. ● Repairs /replaces pumps and systems. ● Identifies tools and equipment used in the service and repair of fixtures |
| <p>2. Drainage system blockage troubleshooting.</p> | <ul style="list-style-type: none"> ● Repairs/replaces defective piping. ● Correctly identify location of stoppage. ● Describes how best to clear pipeline obstruction. ● Determines the proper use of the drain cleaning equipment. ● Describes the proper use of PPE. ● Lists the dangers of chemical drain cleaners |
| <p>2. Solar thermal system troubleshooting. (Reference NABCEP 12.1-12.6)</p> | <ul style="list-style-type: none"> ● Reference NABCEP 12.1-12.6) ● Demonstrates proficiency in using tools and materials required for maintenance and |

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| | <p style="color: green;">troubleshooting</p> <ul style="list-style-type: none"> <li style="color: green;">● Interprets installation manual, wiring diagrams, drawings, and other specifications to plan maintenance or repair work <li style="color: green;">● Determines evaluation points for system monitoring, maintenance and troubleshooting (i.e., sensor calibration, heat exchanger fluid integrity, pump operation) <li style="color: green;">● Identifies cause of problems based on evaluation <p style="color: green;">Results</p> <ul style="list-style-type: none"> <li style="color: green;">● Determines what repairs or system modifications are needed to restore the system to its baseline operating conditions <li style="color: green;">● Performs any identified repairs or modifications to restore system to manufacturer's or operator's specifications |
|--|---|

[Link to Proficiency Scale](#)

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|--------------------------|--------------------------|---------------------------------|

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| <ul style="list-style-type: none"> ● Fixing ● Why it broke ● Cleaning ● Worn out ● Noise ● Testing ● Old parts ● Taking apart | <ul style="list-style-type: none"> ● Remediation ● Diagnosis ● Maintenance ● Degradation ● Indication ● Verification ● Replacement ● Disassembly | <ul style="list-style-type: none"> ● Preventative Maintenance ● Root Cause Analysis ● Descaling / Flushing ● Erosion / Galvanic Corrosion ● Water Hammer / Cavitation ● Manometer Testing / Delta T ● OEM Components (Original Equipment Manufacturer) ● Rebuild / Overhaul |
|---|--|---|

Trade Math Crossover: **(VOG: Problem Solver)**

Focus: Diagnostic math, efficiency, and system restoration.

1. **Thermal Efficiency Loss (Heating):** A technician is servicing an older oil-fired boiler. The manufacturer states the unit originally operated at 85% efficiency. After performing a combustion analysis, the technician finds the unit is currently operating at only 72% efficiency due to soot buildup. If the homeowner spends \$3,200 annually on heating oil, calculate exactly how much money is being "wasted" per year due to this loss in efficiency.
2. **Solar Thermal Collector Performance:** A residential solar thermal system has a 40-square-foot collector. On a clear day, the collector receives 2,000 BTUs of solar energy per square foot. If the system has an overall efficiency of 60% in converting that solar energy into heated water, calculate the total BTUs added to the household's water storage tank over the course of the day.
3. **Drip Waste and Water Conservation:** During a service call, a student identifies a "slow leak" in a kitchen faucet that drips at a rate of 15 milliliters per minute.
 - **Step A:** Calculate how many liters are wasted in a 24-hour period.
 - **Step B:** If there are 3.785 liters in a gallon, how many gallons are wasted in one month (30 days)?

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- **Step C:** If the local utility charge is \$0.005 per gallon, what is the monthly cost of this "small" leak?
- 4. **Temperature Rise (Troubleshooting):** An electric water heater is underperforming. To check the heating elements, a technician measures the "Temperature Rise." If the cold water entering the tank is 52°F and the hot water leaving the tank is 118°F, calculate the temperature rise. If the system's design calls for a 75°F rise to meet the household's peak demand, by how many degrees is the system currently failing?
- 5. **Ohm's Law in Repair (Electrical Crossover):** When troubleshooting a 240-volt electric water heater element, a technician uses a multimeter to check resistance. According to the manufacturer, a 4,500-watt element should have a resistance of approximately 12.8 ohms ($R = V^2/P$). If the student measures the resistance and finds it is 45 ohms, use math to explain whether the element is functioning correctly or needs to be replaced.
- 6. **Repair Orders:** If a customer's bill totals \$235.90, and they have a credit of \$28.50 plus a 10% discount, what is the total that you will be charging them?

Resources to compliment learning-

- Modern Plumbing Textbook (chapter 30)
- International Plumbing (section 7)
- NABCEP Solar Thermal Guide
- Hydronic Heating: Systems and Application

Crossover to Apprenticeship Standards:

- A0700 Intro to Plumbing
- A0031 Basic Blueprint Reading

VOG Portfolio Collection Examples:

VOG- Work Ready:

- Students will create mock customer invoices for various service calls to become proficient in pricing and invoicing.

VOG Trait: A Problem Solver

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- **Example:** A student identifies a malfunctioning solar thermal pump. Instead of just replacing it, they use diagnostic tools to determine if the failure was caused by a faulty sensor or a scale buildup in the heat exchanger, then develops a plan for a long-term fix.

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**CONNECTICUT TECHNICAL EDUCATION
AND CAREER SYSTEM**

Plumbing, Heating & Cooling

Grade 11

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CTECS Plumbing, Heating & Cooling
Grade 11 Curriculum

| | |
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| 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 PHC environments. | |
| Essential Question(s): 1. How does the culture of safety impact our lives outside of the classroom. | |
| Learning Outcomes | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 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 <ul style="list-style-type: none"> ● 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 |

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| <p>11-1.4 Precautions with servicing rotating components.</p> | <ol style="list-style-type: none"> 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 |
| <p>11-1.5 Safety concerns related to servicing refrigeration system.</p> | <ol style="list-style-type: none"> 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. |
| <p>11-1.6 Dangers of working on energized live equipment.</p> | <ol style="list-style-type: none"> 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. |
| <p>11-1.7 Unsafe driving consequences.</p> | <ol style="list-style-type: none"> 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- PHC 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”).

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| Tier 1 (Everyday) | Tier 2 (Academic) | Tier 3 (Technical/Trade) |
|--|--|--|
| <ul style="list-style-type: none"> • Air-purifying respirator • Confined space • lockout/tagout (LOTO) • Occupational Safety and Health Act (OSHA) • Personal protective equipment (PPE) • | <ul style="list-style-type: none"> • Hazard Communication Standard (HCS) • Pictogram hazard • Safety data sheet (SDS) • Stationary refrigerant Detector • Supplied-air respirator • Signal word • Worker's compensation | <ul style="list-style-type: none"> • Globally Harmonized System • (GHS) • ASHRAE Standard 34 • Authorized person • Competent person • Qualified person • Designated person • |

Trade Math Crossover:

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: $12 \text{ ft (height)} < 13.5 \text{ ft (required distance)}$.
 - 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.

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- 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.

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- 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.
-

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 ($8' \times 8' \times 8' = 512$ 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 %: $(107.5 - [100 \times 0.21]) \div 512 = \sim 16.8\%$.
 - 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.
-

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:

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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 PHC 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.

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| Priority Standard 11-2: Knowledge of basic electricity, electrical circuits and AC electric motors | |
|---|---|
| Big Idea(s): 1. Applying knowledge of circuits and motors allows technicians to power, control, and troubleshoot PHC systems efficiently. | |
| Essential Question(s): 1. How does the flow of electric current impact the way we use energy in everyday life? | |
| Learning Outcomes | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 11-2.1 Applications of magnetism in electricity | 1. Define magnetic theory 2. Exhibit the use of the appropriate meter to check basic electrical components. |
| 11-2.2 Low voltage wiring and controls required for heating and cooling equipment to operate. | 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 |
| 11-2.3 Various three phase electric motor theories <ul style="list-style-type: none"> ● Electronically controlled motor ● Variable-speed motor ● Three-phase motor ● Identify Wye and Delta motors | 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.). |

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| | <ol style="list-style-type: none"> 5. Explain operation and application of: different three phase motors |
| <p>11-2.4 Types of electrical loads; Capacitive, Inductive, resistive</p> | <ol style="list-style-type: none"> 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. |
| <p>11-2.5 Principles of solid-state switching devices</p> | <ol style="list-style-type: none"> 1. Discuss how solid-state devices control flow of electrons without mechanical switches that wear out due to friction and sparks 2. Identify principles of solid-state switching devices |
| <p>11-2.6 Electricity production and distribution</p> | <ol style="list-style-type: none"> 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 |
| <p>11-2.7 The differences in Wye (Y) and Delta (D) distribution systems</p> | <ol style="list-style-type: none"> 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 |

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| <p>11-2.8 Operation and application of motors</p> | <ol style="list-style-type: none"> 1. Identify different motor types and uses, small axial fans, squirrel blowers, compressors etc. 2. Explain proper horsepower of replacement motors | |
| <p>11-2.9 Starting components associated with single-phase and three-phase motors</p> <ul style="list-style-type: none"> ● centrifugal switch ● current coil relay ● potential relay ● PTC relay | <ol style="list-style-type: none"> 1. Identify single phase starting components 2. Identify contactors and motor starters | |
| <p>11-2. Detailed instructions for wiring circuits interpretation.</p> | <ol style="list-style-type: none"> 1. Identify electrical switch and load symbols used in diagrams. 2. Draw basic electrical circuits that demonstrate an understanding of switches controlling loads | |
| <p><u>Link to Proficiency Scale</u></p> | | |
| <p>Tiered Vocab- PHC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:</p> <ul style="list-style-type: none"> ● 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"). | | |
| <p>Tier 1 (Everyday)</p> | <p>Tier 2 (Academic)</p> | <p>Tier 3 (Technical/Trade)</p> |
| <ul style="list-style-type: none"> ● Alternating current(ac) ● ampere ● atom ● brushes ● conductor ● current ● electricity ● Direct current(dc) ● Electricity | <ul style="list-style-type: none"> ● AWG ● Closed ● Circuit ● Circuit breaker ● Dielectric ● Electrical circuit ● Electrical load ● Fuse ● Grounding | <ul style="list-style-type: none"> ● Bonding ● Brushes ● Capacitance ● Capacitor ● Electromagnet ● Electromagnetism ● Farad(F) ● Induced magnetism ● Induction |

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| <ul style="list-style-type: none"> • Electron • Ohm's law • Switch | <ul style="list-style-type: none"> • Open circuit • Closed circuit • Ground fault interrupter • Load • Resistance • Short circuit • Single phase • Three phase • Watt's law | <ul style="list-style-type: none"> • 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 ($6.2 \text{ times } 1.25 + 1.8 + 0.5 = 10.05$ 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

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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.

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| <p>Priority Standard 11-3: The use of building codes and manufacturers' installation instructions on current production jobs</p> | |
| <p>Big Idea(s):</p> <ol style="list-style-type: none"> Understanding and following codes and manufacturer instructions ensures systems are installed safely, legally, and to industry standards. | |
| <p>Essential Question(s):</p> <ol style="list-style-type: none"> Who writes the codes used for installing mechanical systems or building structures? Why are codes important? Who enforces the use of codes? | |
| <p>Learning Outcomes</p> | |
| <p><i>Students will know:</i></p> | <p><i>As evidenced by:</i></p> |
| <p>11-3.A Codes for-</p> <ul style="list-style-type: none"> Safe installations Energy efficiency Proper venting of combustion gases Fresh air considerations | <ol style="list-style-type: none"> Explain the need for building codes to assure safety throughout our industry when installing, servicing, or repairing PHC equipment. Demonstrate an awareness of their limitations, altogether ensuring a safe alteration to building structure while cooperating with others on site. |
| <p>11-3.B The names of the three model codes</p> <ul style="list-style-type: none"> BOCA SBCCI ICBO | <ol style="list-style-type: none"> Explain code models. |
| <p>11-3.C Codes and standards for the applicable area, locality, and state.</p> | <ol style="list-style-type: none"> Identify necessary codes from the International mechanical code when regulations are not specified otherwise. Explain CT code models used in most area |
| <p>11-3. D Relationship between codes and manufacturers' installation instructions.</p> | <ol style="list-style-type: none"> Prepare to install or repair PHC equipment, referring to the manufacturers' installation instructions. Give examples of the local building and energy codes when directed to do so. |

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| | <ol style="list-style-type: none"> 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 |
| <p>11-3.E How to identify pertinent standards published by AGA, AMCA, ANSI, ARI, ASHRAE, IED, ISO, SMACNA, and UL.</p> | <ol style="list-style-type: none"> 1. Describe about organizations which investigate and lobby for manufacture, installation, and service standards |
| <p>11-3.F The methods for adapting a Solar Thermal System Design (Reference NABCEP 3.1-3.9)</p> | <p>(Reference NABCEP 3.1-3.9)</p> <ol style="list-style-type: none"> 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. |

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| | <p>9. Inspect all provided system components for damage prior to installation</p> |
| <p>11-3.G Mechanical/Plumbing Equipment and other components onto Solar Thermal Systems: Reference NABCEP: 8.1-8.5</p> <ul style="list-style-type: none"> ● System components ● Location of components ● System monitoring components ● Heat exchanger ● Heat exchanger fluids | <p>Reference NABCEP: 8.1-8.5</p> <ol style="list-style-type: none"> 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 |

[Link to Proficiency Scale](#)

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| Tier 1 (Everyday) | Tier 2 (Academic) | Tier 3 (Technical/Trade) |
|--|--|---|
| <ul style="list-style-type: none"> ● Service ● Specialty | <ul style="list-style-type: none"> ● Building inspector certification | <ul style="list-style-type: none"> ● PHCR drafter ● PHCR engineer |

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| <ul style="list-style-type: none">• certification | <ul style="list-style-type: none">• Energy auditor estimator• PHCR designer. | <p>Installation</p> <ul style="list-style-type: none">• 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".

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:**
 - $70 + (4 \text{ times } 5) + (2 \text{ times } 2.5) = ?$

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- **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?
-

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 "upsized" to 8-gauge wire despite the manufacturer's minimum.
-

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.

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- **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 PHC production jobs.

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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.)

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| <p>Priority Standard 11-4: Calculate total heat gain/loss for the proper sizing of heating/cooling equipment.</p> | |
| <p>Big Idea(s):</p> <ol style="list-style-type: none"> 1. Accurate load calculations are essential for selecting properly sized PHC equipment that delivers energy efficiency and comfort. | |
| <p>Essential Question(s):</p> <ol style="list-style-type: none"> 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? | |
| <p>Learning Outcomes</p> | |
| <p><i>Students will know:</i></p> | <p><i>As evidenced by:</i></p> |
| <p>11-4.A Heat transfer tables ("U," "K," "R").</p> | <ol style="list-style-type: none"> 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 |
| <p>11-4.B Heat gain/loss calculation to select properly sized PHCR equipment</p> | <ol style="list-style-type: none"> 1. Select properly sized PHCR equipment for applications from calculations. |
| <p>11-4.C Blueprints – size rooms, etc. for the breaking down values needed for the load calculation.</p> <ul style="list-style-type: none"> • Net exposed wall area • Ceiling area • Floor area • Windows (glass area) • Door area | <ol style="list-style-type: none"> 1. Apply trade related math through calculating necessary net areas of the building structure, subject to heat gain/loss. 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 |
| <p>11-4.D Tables of specific heat values, latent heat, and heat of respiration.</p> | <ol style="list-style-type: none"> 1. Explain use of design conditions for different climates |
| <p>11-4.E Vapor barriers.</p> | <ol style="list-style-type: none"> 1. Explain vapor barriers and their effect on load calculations |

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1. Determine design data from given blueprint

[Link to Proficiency Scale](#)

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| Tier 1 (Everyday) | Tier 2 (Academic) | Tier 3 (Technical/Trade) |
|--|--|---|
| <ul style="list-style-type: none"> • Crawlspace • Insulation | <ul style="list-style-type: none"> • Outdoor design temperature (ODT) • Manual j • Total heat loss • Sustainable • Indoor design temperature (IDT) • Heat gain • Heat lag • Heat leakage • Heat load • Heat loss • Heat transfer rate | <ul style="list-style-type: none"> • Emissivity • Heat transfer multiplier • (HTM) • thermal conductance • (C-value) M • thermal conductivity • (K-value) • thermal 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.

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- **The Formula:** $Q = U \times A \times \Delta T$ (Heat Loss = $1 / R\text{-value} \times \text{Area} \times \text{Temperature Difference}$).
 - **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

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

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.

Living Document

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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 PHC 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

| <i>Students will know:</i> | <i>As evidenced by:</i> |
|--|--|
| 11-5.A Ductwork pressures | <ol style="list-style-type: none"> 1. Explain duct pressures 2. Explain how ductwork pressures affect equipment, ductwork, and register/diffuser sizing |
| 11-5.B Air distribution system. | <ol style="list-style-type: none"> 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. | <ol style="list-style-type: none"> 1. Draw layout of return and supply systems. |
| 11-5.D Trunk and branch ducts design | <ol style="list-style-type: none"> 1. Demonstrate ability to size trunk and branch ducts by equal friction method. |
| 11-5.E Registers, grilles, and diffusers. | <ol style="list-style-type: none"> 1. Demonstrate ability to size supply registers, return grilles, and diffusers. |
| 11-5.F Types of fans/blowers | <ol style="list-style-type: none"> 1. Explain different types of fans/blowers |
| 11-5.G Proper rotation of blowers | <ol style="list-style-type: none"> 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. | <ol style="list-style-type: none"> 1. Demonstrate the ability to check fans/blowers' performance. |

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|--|---|
| 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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|---|--|--|
| <ul style="list-style-type: none"> • Flow • Fan • Duct • Elbow • Grille • Register • Whole house fan | <ul style="list-style-type: none"> • Butterfly damper device • Friction rate • Friction loss • Forced draft • Gable fan • Induced draft • Primary air • Effective length • Duct board • Diffuser • Unvented attic • Vented attic | <ul style="list-style-type: none"> • External static pressure (ESP) • Device pressure losses (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.

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- **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 inch 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

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.

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- **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 PHC work.

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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.

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| <p>11-6.C Incomplete combustion of fuel gases and improper venting.</p> | <ol style="list-style-type: none"> 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. |
| <p>11-6.D Fuel gas safety</p> | <ol style="list-style-type: none"> 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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|---|---|--|
| <ul style="list-style-type: none"> • Combustion • Flammability • Limit | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • 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 |

Connecticut Technical Education and Career System

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- 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

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:

CTECS Plumbing, Heating & Cooling

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.

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

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| 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 | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 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 <ul style="list-style-type: none"> ● "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 |

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| 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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|---|--|--|
| <ul style="list-style-type: none"> • 100% shutoff • Atmospheric gas burner • combustion • | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • 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 |

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| | | |
|--|---|--|
| | <ul style="list-style-type: none"> • Drip leg • Combustion air • Direct-venting system • Combination gas valve • Draft regulator | <ul style="list-style-type: none"> • 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?

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?

3. Two-Stage Heating Logic (Manifold Pressure)

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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.
-

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 ($40 + 5 \text{ times } 5 = 65 \text{ feet}$).
 - **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.
-

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.
-

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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.

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:

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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.)

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| | |
|---|--|
| 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 | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 11-8.A Methods for startups and adjusting gas appliances for proper operation to the manufacturer's specifications and efficiency. | <ol style="list-style-type: none"> 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. | <ol style="list-style-type: none"> 1. Check gas valve regulator operation |
| 11-8.C Operation and the methods of pilot/burner ignition | <ol style="list-style-type: none"> 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 | <ol style="list-style-type: none"> 1. Explain the information required to start gas appliances to manufacture requirements |

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| | |
|---|---|
| <p>11-8.E Heating appliance testing and safety systems</p> | <ol style="list-style-type: none"> 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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- Tier 3: Low-frequency, domain-specific technical terms (The "Language of the Trade").

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|--|---|---|
| <ul style="list-style-type: none"> • 100% shutoff • Atmospheric gas burner • combustion • Flammability • Limit • Ignition system • Ignition temperature | <ul style="list-style-type: none"> • 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 • High-efficiency gas furnace • High-limit switch • End switch • Flame rectification | <ul style="list-style-type: none"> • 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 • 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.

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- **The Formula:** Output BTUs = 1.08 CFM times Temperature Rise (ΔT).
- **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 ΔT : $\Delta T = 80,000 \text{ div } (1.08 \text{ times } 1,200)$.

2. Calculate the expected rise ($80,000 \text{ div } 1,296 = 61.7^\circ \text{ F}$).

- **The Field Test:** If the return air is 70° F and the supply air is 150° F ($\Delta T = 80^\circ \text{ F}$), 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- 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: 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

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

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| | | |
|--|---|---|
| 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 PHC industry standards. | | |
| Essential Question(s): 1. What are the two major areas to check when trouble shooting a system? | | |
| Learning Outcomes | | |
| <i>Students will know:</i> | <i>As evidenced by:</i> | |
| 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 | |
| <u>Link to Proficiency Scale</u> | | |
| <p>Tiered Vocab- PHC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:</p> <ul style="list-style-type: none"> • 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) |
| <ul style="list-style-type: none"> • 100% shutoff • Combination gas valve • combustion • Draft regulator • Flammability • Limit • Gas burner • Gas manifold | <ul style="list-style-type: none"> • Annual fuel utilization efficiency (AFUE) • Combustion efficiency • Complete combustion • Flame rollout • Excess air • Atmospheric gas burner • High-efficiency gas furnace | <ul style="list-style-type: none"> • Category I furnace • Category II furnace • Category III furnace • Category IV furnace • Electric interlock electromagnetic interference (EMI) • Hard lockout |

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| | | |
|--|---|--|
| | <ul style="list-style-type: none">• High-limit switch• Ignition system• Ignition temperature• Drip leg• End switch• Flame rectification• Combustion air | <ul style="list-style-type: none">• 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?

3. Temperature Rise (The Airflow Formula)

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

- **The Formula:** $CFM = \text{Output BTUs} \div 1.08 \text{ times Temp Rise } (\Delta T)$
- **The Scenario:** A furnace has an output of **80,000 BTUs**. The return air is **70°F** and the supply air is **160°F** ($\Delta T = 90^\circ\text{F}$).
- **The Math:** 1. Calculate the current CFM ($80,000 \div 1.08 \text{ times } 90$).

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.
-

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" ($[3.5 - 3.1] \div 3.5$).

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"?
-

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 \div 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**.

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- **The Diagnostic:** Calculate the actual wattage ($14,400 \div 55 = 261$ 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.

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

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|--|---|
| <p>Priority Standard 11-10: Handle refrigerants while comprehending industry environmental issues regarding them.</p> | |
| <p>Big Idea(s):</p> <ol style="list-style-type: none"> Understand superheat, subcooling, and coil temperature differences helps technicians evaluate system health and cooling efficiency. | |
| <p>Essential Question(s):</p> <ol style="list-style-type: none"> What are the reasons the 608 Certification to PHC technicians? | |
| <p>Learning Outcomes</p> | |
| <p><i>Students will know:</i></p> | <p><i>As evidenced by:</i></p> |
| <p>11-10.A Refrigerants Handling</p> | <ol style="list-style-type: none"> Exhibited safe refrigerant handling and applications. Demonstrated proper system charging by weight and superheat & sub-cooling, PT relationships. Describe the methods of determining when a recovery cylinder is full. Describe system dependent and self-contained recovery equipment. Describing the problems associated with mixing of refrigerants. Explaining how to determine empty cylinder weight. Calculating 80% full weight of cylinder and refrigerant Explaining the problems associated with contaminants such as acid, oil, and old refrigerant left in a refrigerant system after recovery |
| <p>11-10.B ASHRAE Refrigerant Safety Classification of Refrigerants for Toxicity and Flammability</p> | <ol style="list-style-type: none"> Categorize different classes of refrigerants, physical and chemical properties in essay form. |

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| <p>11-10.C Improper handling or disposal and emission into the atmosphere.</p> | <ol style="list-style-type: none"> 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 |
| <p>11-10.D Proper recycle, recover, reclaim refrigerant to EPA 608 standards at all types 1, 2, and 3</p> | <ol style="list-style-type: none"> 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 |
| <p>11-10.E Manually pump down a system with liquid line service valves</p> | <ol style="list-style-type: none"> 1. Demonstrate manual pump down a system. |
| <p>11-10.F Isolate system components</p> | <ol style="list-style-type: none"> 1. Demonstrate how to isolate system components. |
| <p>11-10.G EPA certification requirements</p> | <ol style="list-style-type: none"> 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](#)

Tiered Vocab- PHC 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) |
|---|---|--|
| <ul style="list-style-type: none"> • Capture • Chlorine | <ul style="list-style-type: none"> • Ozone depletion potential (ODP) | <ul style="list-style-type: none"> • Active recovery • Back seated valve |

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| | | |
|--|---|---|
| <ul style="list-style-type: none"> • Global warming • Hazardous waste • Reclaim • Recover • Recycle • Refrigerants | <ul style="list-style-type: none"> • Global warming potential (GWP) • De minimus • EPA certification • Universal certification • Environmental Protection Agency (EPA) • Clean Air Act (CAA) • Atmospheric balancing • Active recovery • Pump down | <ul style="list-style-type: none"> • 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: $0.0625 \text{ times } 3.04 \text{ times } 100 = 19\%$.

- **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.

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- **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.
-

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).
-

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

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- **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.

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| <p>Priority Standard 11-11: Refrigeration cycle and superheat, sub-cooling, and coil temperature differences.</p> | |
| <p>Big Idea(s):</p> <ol style="list-style-type: none"> 1. PHC 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. | |
| <p>Essential Question(s):</p> <ol style="list-style-type: none"> 1. Why would a technician need to know what the temperature and pressures are throughout the refrigeration system? | |
| <p>Learning Outcomes</p> | |
| <p><i>Students will know:</i></p> | <p><i>As evidenced by:</i></p> |
| <p>11-11.A The four major components of the vapor compression refrigeration system.</p> | <ol style="list-style-type: none"> 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 |
| <p>11-11.B Types of evaporators and their uses in the refrigeration and air conditioning field.</p> | <ol style="list-style-type: none"> 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 |

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| | | |
|--|--|--|
| | <p>6. Calculate superheat on all evaporators</p> | |
| <p>11-11.C Types of condensers and uses in the refrigeration and air conditioning field.</p> | <ol style="list-style-type: none"> 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 | |
| <p>11-11.D State & condition of refrigerant in the system; Liquid, Vapor, Sub-cooled liquid, Superheated Vapor</p> | <ol style="list-style-type: none"> 1. Explain the changes that the refrigerant goes through as it travels through the system moving heat | |
| <p>Link to Proficiency Scale</p> | | |
| <p>Tiered Vocab- PHC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:</p> <ul style="list-style-type: none"> • 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"). | | |
| <p>Tier 1 (Everyday)</p> | <p>Tier 2 (Academic)</p> | <p>Tier 3 (Technical/Trade)</p> |
| <ul style="list-style-type: none"> • compressor • condenser • conduction • convection • Condensation • Evaporation | <ul style="list-style-type: none"> • High-pressure side • Hot Gas discharge line • Liquid line • Low-pressure side • Pressure drop • Reciprocating | <ul style="list-style-type: none"> • Accumulator • Crankcase heater • Cooling tower • Filter drier • Flash gas • Off cycle |

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| | | |
|--|---|---|
| | <ul style="list-style-type: none"> • Refrigerant • Subcooled • Suction line • Superheat • evaporator | <ul style="list-style-type: none"> • On cycle • Liquid receiver • Series connection • Temperature difference (td) • 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** ($32 - 20 = 12^\circ \text{ F}$).

2. If the actual pipe temperature is 45°F, calculate the **Superheat** using the Dew Point ($45 - 32 = 13^\circ \text{ F}$ 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

Connecticut Technical Education and Career System

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- Unit 24 Expansion Devices

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:** 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).

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- **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.

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|---|---|
| Priority Standard 11-12: Inside and outside production and the possibility of Work based Learning (WBL) | |
| Big Idea(s): | |
| <ol style="list-style-type: none"> 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): | |
| <ol style="list-style-type: none"> 1. What are marketable skills? 2. How can you benefit from WBL? | |
| Learning Outcomes | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 11-12.A Expectations of all parties involved in work based learning. | <ol style="list-style-type: none"> 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 | <ol style="list-style-type: none"> 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. | <ol style="list-style-type: none"> 1. Discuss verbal and non-verbal communication. List ways negative |

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| | |
|---|---|
| | <p>nonverbal communication may be displayed.</p> <ol style="list-style-type: none"> 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. | <ol style="list-style-type: none"> 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 | <ol style="list-style-type: none"> 1. Follow-up activity after completion of the interview. 2. Review interviews. |
| 11-12. Develop a readiness guide for the worksite. | <ol style="list-style-type: none"> 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 ($\$150 \div 10 = 15$ 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:

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- 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 PHC unit's condensate lines and power supplies are installed without interfering with other trades' work.

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CONNECTICUT TECHNICAL EDUCATION
AND CAREER SYSTEM

Plumbing, Heating & Cooling
Grade 12

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CTECS Plumbing, Heating & Cooling
Grade 12 Curriculum

| | | |
|--|---|---|
| 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 | | |
| <i>Students will know:</i> | | <i>As evidenced by:</i> |
| 12-1.1 Dangers associated with fuel oil fumes and leaks | <ol style="list-style-type: none"> 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. | <ol style="list-style-type: none"> 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 | <ol style="list-style-type: none"> 1. Protect skin from contact with oil 2. Demonstrate proper venting while working on burners | |
| <u>Link to Proficiency Scale</u> | | |
| <p>Tiered Vocab- PHC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:</p> <ul style="list-style-type: none"> • 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) |
| <ul style="list-style-type: none"> • Combustion | <ul style="list-style-type: none"> • atomizing | <ul style="list-style-type: none"> • Gun-type burner |

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| | | |
|--|--|--|
| <ul style="list-style-type: none"> • Boiler • Furnace • Water heater • Chimney • Carbon • Oil filter • Fuel oil • vaporized • Gap | <ul style="list-style-type: none"> • Oil furnace • Oil pump • orifice • Vent alarm • Supply line • Return oil line • Vent pipe • Fill pipe • Direct vent • Viscosity | <ul style="list-style-type: none"> • 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:** $\Delta V = V_0 \text{ times } \beta \text{ times } \Delta T$
 - (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 ($\Delta T = 130 - 60$).

2. Calculate the change in volume ($\Delta V = 4 \text{ times } 0.0016 \text{ times } 70$).

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- **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 NO_x), combustion must be "Stoichiometric"—the perfect ratio where all fuel and all oxygen are consumed.

- **The Data:** Burning **1 cubic foot of Methane (CH₄)** ideally produces **1 cubic foot of CO₂** and requires **2 cubic feet of O₂** (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 CO₂ 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° F (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.

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- **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.
-

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 CO₂" 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?

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/ Carlin Manuals

OSHA.Gov:

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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: 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.

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| 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? | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 12-2.A Components used in all types of oil systems. | 1. Identify oil systems parts |
| 12-2.B Types of oil heating appliances <ul style="list-style-type: none"> ● 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 <ul style="list-style-type: none"> ● 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 <ul style="list-style-type: none"> ● One pipe ● Two pipe ● Transfer pump to secondary storage | Describe oil tank installation and piping: <ol style="list-style-type: none"> 1. One pipe 2. Two pipe 3. Transfer pump to secondary storage |

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|---|---|
| 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 <ul style="list-style-type: none"> ● Single limits ● Triple aqua stats ● Fan/limits | Testing limit controls <ol style="list-style-type: none"> 1. Single limits 2. Triple aqua stats 3. Fan/limits |

[Link to Proficiency Scale](#)

Tiered Vocab- PHC 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) |
|---|--|--|
| <ul style="list-style-type: none"> ● Boiler ● Combustion ● Furnace ● Water heater ● Chimney ● Carbon ● Fuel oil ● vaporized ● Gap ● Oil furnace ● Electrodes ● Oil pump | <ul style="list-style-type: none"> ● Viscosity ● atomizing ● Burner fan ● Flexible coupling ● orifice ● Primary control ● Spray angle ● Stack control ● Transient light | <ul style="list-style-type: none"> ● 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 |

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- 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:** $GPH_{actual} = GPH_{rated} \times \sqrt{P_{actual} \div 100}$
- **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**.

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- **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 ($50 \div 10$).
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:** $V = I \text{ times } R$ (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 ($24 \div 0.015$).
-

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** (ΔT) 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.

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- **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/ 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 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.

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- **Example:** A student could present a project outlining the several types of fuel tanks installed in the trade.

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| | |
|---|---|
| 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 | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 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 <ul style="list-style-type: none"> ● 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 |

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|---|---|
| 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 |

[Link to Proficiency Scale](#)

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| Tier 1 (Everyday) | Tier 2 (Academic) | Tier 3 (Technical/Trade) |
|---|---|--|
| <ul style="list-style-type: none"> • Gap • Boiler • Furnace • Water heater • Chimney • Carbon • Oil filter • Fuel oil | <ul style="list-style-type: none"> • Atomizing • Burner fan • Draft control • Electrodes • Oil furnace • Oil pump • orifice • Transient light • Vaporized • Viscosity | <ul style="list-style-type: none"> • Cad cell • Direct vent • Air band • Combustion • Gun-type burner • Bleed port • Pressure tap plug • Two-stage oil pump • Single-stage oil pump • Solid-state igniter • Intermittent ignition • Interrupted ignition • Supply line • Vent alarm • Return oil line • Vent pipe • Fill pipe • Above ground tank • Underground tank • Primary control |

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- Spray angle
- Stack control
- Flexible coupling
- Ignition transformer
- Isolation relay

Trade Math Crossover:

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:** $GPH_{New} = GPH_{Rated} \times \sqrt{P_{New} / P_{Rated}}$
 - **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: $(0.750 \div 0.85)^2 \times 100 = ?$
 - **The Result:** You must set the pump to 128 PSI.
-

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.
-

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.

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- **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).
-

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.
-

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% CO₂ 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.
-

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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

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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

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- **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.

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| | | |
|--|--------------------------|---|
| Priority Standard 12-4: Systematically troubleshoot and service an oil system. | | |
| Big Idea(s): | | |
| <ol style="list-style-type: none"> 1. Effective troubleshooting of oil systems requires critical thinking, technical skills, and adherence to safety protocols to ensure peak system performance. | | |
| Essential Question(s): | | |
| <ol style="list-style-type: none"> 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 | | |
| <i>Students will know:</i> | | <i>As evidenced by:</i> |
| 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 | | Demonstrate testing of fuel unit pressures |
| <ul style="list-style-type: none"> • Nozzle • Vacuum | | <ol style="list-style-type: none"> 1. Nozzle 2. Vacuum |
| 12-4.D Limit controls | | Explain testing limit controls |
| <ul style="list-style-type: none"> • Single limits • Triple aqua stats • Fan/limits | | <ol style="list-style-type: none"> 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 |
| Link to Proficiency Scale | | |
| <p>Tiered Vocab- PHC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:</p> <ul style="list-style-type: none"> • 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) |

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| | | |
|--|---|---|
| <ul style="list-style-type: none"> • Boiler • Furnace • Water heater • Chimney • Carbon • Oil filter • Fuel oil | <ul style="list-style-type: none"> • Gap • atomizing • Burner fan • Electrodes • Oil furnace • Oil pump • orifice • Transient light • vaporized • Viscosity | <ul style="list-style-type: none"> • Air band • Isolation relay • Combustion • Gun-type burner • Bleed port • Pressure tap plug • Two-stage oil pump • Single-stage oil pump • Solid-state igniter • Intermittent ignition • Interrupted ignition • Vent alarm • Primary control • Spray angle • Stack control • Flexible coupling • Ignition transformer • Cad cell • Draft control • Above ground tank • Underground tank • Supply line • Return oil line • Direct vent • Vent pipe • Fill pipe |
|--|---|---|

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.

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- **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 $R > 1,600 \ \Omega$ while the flame is active, the cell is dirty or misaligned.
-

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 ($[(0.92 - 0.85) \div 0.85]$).

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.
-

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, CO₂ and O₂ have an inverse mathematical relationship. For every **1% drop in O₂**, CO₂ should rise by approximately **0.7%**.
- **The Scenario:** Your analyzer shows **6% O₂** and **9% CO₂**.
- **The Math:** 1. Perfect oil combustion is roughly **15.4% CO₂** at **0% O₂**.

2. Calculate the "Expected CO₂" for your O₂ reading: $15.4 - (6 \text{ times } 0.7) = 11.2\%$.

- **The Diagnostic:** Since your actual CO₂ (9%) is much lower than the expected CO₂ (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).
-

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.

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- **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: $40 \div 10 = 4$ 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"?
-

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.

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

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- 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.

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| Priority Standard 12-5: Industry EPA standards for safety and environmental issues regarding refrigerant. | |
|---|--|
| Big Idea(s): 1. EPA regulations promote sustainability, and PHC 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 | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 12-5.A EPA certification requirements <ul style="list-style-type: none"> ● 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. |

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| | |
|--|---|
| 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 |

[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) |
|---|---|--|
| <ul style="list-style-type: none"> • Capture • Chlorine • Global warming • Hazardous waste • Reclaim • Recover • Recycle • Refrigerants | <ul style="list-style-type: none"> • Ozone depletion potential (ODP) • Global warming potential (GWP) • De minimus • EPA certification • Universal certification • Active recovery • Atmospheric balancing | <ul style="list-style-type: none"> • 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:

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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: $15 \div 450 = 0.0333$

2. Time Factor: $365 \div 90 = 4.05$

3. Annualized Rate: $0.0333 \text{ times } 4.05 \text{ times } 100 = \mathbf{13.5\%}$

- **The Compliance Check:** Does this exceed the **20%** limit for commercial refrigeration? (No, but it is approaching it).
-

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: $47.7 \text{ times } 0.80 = \mathbf{38.16}$ lbs.

2. Total Scale Weight: $38.16 \text{ (gas)} + 28.1 \text{ (tank)} = \mathbf{66.26}$ 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 ($5 \div 10 = 50\%$).
 - **The Legal Result:** You must continue recovering for another 5" Hg before you can legally open the system to the atmosphere.
-

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 CO₂

2. **R-32 Impact:** 8 lbs. times 675 = **5,400 lbs.** of CO₂

- **The Comparison:** By switching to the newer R-32 refrigerant, the environmental "damage" of a leak is reduced by what percentage? ($16,704 - 5,400 \div 16,704$).
-

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.**

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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

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- **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.)

Living Document

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| | | |
|---|--------------------------|--|
| Priority Standard 12-6: Describe the mechanical refrigeration cycle and be able to troubleshoot problems. | | |
| Big Idea(s): 1. Understanding the mechanical refrigeration cycle enables technicians to detect faults, make repairs, and ensure consistent system cooling. | | |
| 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? | | |
| Learning Outcomes | | |
| <i>Students will know:</i> | | <i>As evidenced by:</i> |
| 12-6.A Refrigeration system's performance <ul style="list-style-type: none"> ● Evaporator ● Condenser ● Compressor | | <ol style="list-style-type: none"> 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 |
| 12-6.C Service valve positions <ul style="list-style-type: none"> ● Front seat, Mid seat, Back seat | | <ol style="list-style-type: none"> 1. Demonstrate how to front, mid and back seat position for proper operation of 3-way service valves. |
| Link to Proficiency Scale | | |
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| Tier 1 (Everyday) | Tier 2 (Academic) | Tier 3 (Technical/Trade) |

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| | | |
|--|---|---|
| <ul style="list-style-type: none"> • Compressor • Condenser • Conduction • Convection • Evaporator • Reciprocating • Condensation • Refrigerant • Evaporation | <ul style="list-style-type: none"> • High-pressure side • Hot Gas discharge line • Liquid line • Low-pressure side • Pressure drop • Subcooled • Suction line • Superheat | <ul style="list-style-type: none"> • 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.

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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

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"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.

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| 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 | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 12-7.A Tools and instruments needed for checking out air-conditioning and heating systems for proper operation. <ul style="list-style-type: none"> ● 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. <ul style="list-style-type: none"> ● System Charge ● Motor Amperage ● Air flow ● Safety controls ● Voltages ● 3 phase motor rotation | 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. 4. Demonstrate checking operation of electrical control components such as isolating relays etc. |

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|--|--|
| | 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 1 (Everyday) | Tier 2 (Academic) | Tier 3 (Technical/Trade) |
|--|---|---|
| <ul style="list-style-type: none"> • Gas • Liquid • Refrigeration • Supply • Return • Register • Insulation • Thermostat | <ul style="list-style-type: none"> • Gauge pressure • Service valve • btu • Amperage • Vapor | <ul style="list-style-type: none"> • 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

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- **The Math:** 1. **Subcooling:** $110 - 90 = 20^{\circ} \text{ F}$ (High: Target is 10° F)
2. **Superheat:** $55 - 40 = 15^{\circ} \text{ F}$ (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.
-

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:** $\text{CFM} = \text{Sensible Heat (BTU/h)} \div 1.08 \times \Delta T$
 - **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 ΔT : $75 - 62 = 13^{\circ} \text{ F}$.
2. Calculate Expected ΔT : $36,000 \div (1.08 \text{ times } 1,200) = 27.7^{\circ} \text{ F}$.
- **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

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CTECS Plumbing, Heating & Cooling

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" ($\sqrt{3}$) 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.

CTECS Plumbing, Heating & Cooling

| 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 | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 12-8.A Identify the components of the heat pump systems, <ul style="list-style-type: none"> ● 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 <ul style="list-style-type: none"> ● Air to air | 1. Explain the history of heat pump systems as well as different types used. |

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| <ul style="list-style-type: none"> ● Geothermal | | |
|--|---|--|
| Link to Proficiency Scale | | |
| <p>Tiered Vocab- PHC students build a professional vocabulary; we have broken down the terms into three tiers based on the standard educational model:</p> <ul style="list-style-type: none"> ● 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) |
| <ul style="list-style-type: none"> ● charge ● demand ● defrost ● Valve | <ul style="list-style-type: none"> ● Air coil ● Balance point ● Air-source heat pump (ASHHP) ● Air-to-air heat pump ● Air-to-water heat pump ● Pilot-operated reversing ● Heat pump ● Compensator tank ● Auxiliary heat ● Reverse cycle | <ul style="list-style-type: none"> ● 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) |
| <p>Trade Math Crossover:</p> | | |

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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

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

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

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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.**

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| <p>Priority Standard 12-9: Systematically troubleshoot and service an air conditioning system.</p> | |
| <p>Big Idea(s):</p> <ol style="list-style-type: none"> Advanced diagnostic skills in air conditioning systems reduce downtime and improve customer satisfaction through precise, timely repairs. | |
| <p>Essential Question(s):</p> <ol style="list-style-type: none"> When troubleshooting for a suspected electrical problem, list a good step by step procedure to take us to the problem? | |
| <p>Learning Outcomes</p> | |
| <p><i>Students will know:</i></p> | <p><i>As evidenced by:</i></p> |
| <p>12-9. Air conditioning systems performance and operating problems</p> <ul style="list-style-type: none"> ● 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 ● Worn bearings | <ol style="list-style-type: none"> Give an overview of the history as well as different types of air conditioning systems 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) Explain the operation of the components and typical failures of each. Demonstrate troubleshooting techniques both in (electrical and mechanical) on an air conditioning system. Demonstrate use of tools and test equipment following safety practices. |

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| 12-9.B Heating Systems repair | <ol style="list-style-type: none"> 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 | <ol style="list-style-type: none"> 1. Pass test on air conditioning system problems |
| 12-9.D Typical heating system problems | <ol style="list-style-type: none"> 1. Pass test on heating system problems |
| 12-9.E Electrical test instruments to diagnose electrical troubles | <ol style="list-style-type: none"> 1. Pass test on PHC electrical problems 2. Use electrical test instruments to diagnose electrical troubles and correct electrical system problems (VOG-Problem Solver) |

[Link to Proficiency Scale](#)

Tiered Vocab- PHC 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) |
|--|--|--|
| <ul style="list-style-type: none"> • Gas • Liquid • Refrigeration • Amperage • Register • Insulation • thermostat | <ul style="list-style-type: none"> • Gauge pressure • btu • Supply • Return • Watts • CFM • Vapor | <ul style="list-style-type: none"> • Service valve • Saturated • Superheat • Sub cooling • Heat gain • Solar gain • Condensing unit • Air handler • Evaporator • Line set • Liquid line • Suction line |

Trade Math Crossover:

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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** ($52 - 45 = 7^{\circ}\text{F}$).
 - **The diagnosis:** Since $7^{\circ}\text{F} > 3^{\circ}\text{F}$, 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 ($15 \text{ kW} \times 0.1 \text{ hrs.} = 1.5 \text{ kWh}$).

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

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CTECS Plumbing, Heating & Cooling

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.

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- **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.

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| | |
|---|---|
| Priority Standard 12-10: Become acquainted with hydronic heating systems | |
| Big Idea(s): | |
| <ol style="list-style-type: none"> Hydronic systems offer efficient, even heating, and understanding their components and applications expands a technician’s skill set and service options. | |
| Essential Question(s): | |
| <ol style="list-style-type: none"> 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 | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 12-10.A Components of hydronic heating systems. | <p>Explain the purpose of the hydronic heating system component.</p> <ol style="list-style-type: none"> Expansion tank Air scoop Auto feeder Backflow preventer Auto Vent Bleeder Flow check Valve Circulator Boiler P/T gauge Pressure relief Low water cut-off Size Solar pump equipment and accessories based on manufacturers specifications for specific applications. (Reference NABCEP 8.6, 8.7, 9.3) Determine pump location for solar thermal installations Install the solar thermal pump according to the manufacturer’s installation manual |

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|--|--|
| | 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](#)

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

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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) |
|--|---|---|
| <ul style="list-style-type: none"> • DE aeration • Backflow preventer • Radiator • Steam | <ul style="list-style-type: none"> • Air bound • Air scoop • Air vent • aqua stat • Expansion tank • High limit control • Mixing valve • Water feeder • Circulator pump • Relief valve • Zone valve • Series loop • Boiler drain • Low water cutoff | <ul style="list-style-type: none"> • Condensing boiler • Conventional boiler • Dry-base boiler • Underfloor radiant heating system • Expansion steam trap • Fan convector • Flow-control valve • Direct return hydronic system • Reverse return system • Thermostatic mixing valve • Two pipe hydronic system • Wet base boiler |

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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 (ΔT).
- **The Math:** 1. Rearrange the formula: $GPM = 40,000 \div (500 \text{ Times } 20)$.

2. Calculate: $40,000 \div 10,000 = 4.0 \text{ GPM}$.

- **The Diagnostic:** If you measure the actual ΔT and find it is **35°F**, the math proves the water is moving too slowly. What is the actual GPM flowing through that pipe?
-

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: $150 + (10 \text{ times } 2) = 170 \text{ feet}$.

2. Total Head Loss: $1.7 \text{ (hundreds of feet) times } 3 \text{ (loss factor)} = 5.1 \text{ feet of head}$.

- **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

Connecticut Technical Education and Career System

CTECS Plumbing, Heating & Cooling

- 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 (D 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:

D T = T supply – T return

- **VOG Standard:** A typical residential system targets a **D T** of **20°F** (11° C). If the **D 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

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- **Example:** Students can present boiler piping projects including all necessary near boiler components.

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| 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 | | |
| <i>Students will know:</i> | | <i>As evidenced by:</i> |
| 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 | | |
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| | | |
|--|---|---|
| <ul style="list-style-type: none"> • Backflow preventer • DE aeration • Relief valve • Radiator • Steam | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • 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 ($0.9 \div 2.0$).

- **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.

CTECS Plumbing, Heating & Cooling

- **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": $12,000 \div 400 = 30 \text{ BTUs/sq ft.}$
 - **The Design Decision:** Which spacing must the technician use to ensure the room stays warm on the coldest day of the year?
-

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:** $V = \text{GPM times } 0.408 \div d^2$ (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: $(8 \text{ times } 0.408) \div 0.5625 = 5.8 \text{ fps.}$
 - **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

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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.

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- **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 **DT** (T supply – T return) at the boiler.

VOG Trait: Work Ready

- **Example:** Students can present purging air from hydronic lines connected to a boiler.

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| 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 PHC trade? | |
| Learning Outcomes | |
| <i>Students will know:</i> | <i>As evidenced by:</i> |
| 12-12.A Work-based learning. | <ol style="list-style-type: none"> 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. Motivate to accomplish the task at hand. |
| 12-12.B The student contribution in the workplace | <ol style="list-style-type: none"> 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. | <ol style="list-style-type: none"> 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. | <ol style="list-style-type: none"> 1. Outline and describe the three stages of an interview –greeting, exchange and parting. |

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| | 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: $20 + (20 \text{ times } 0.25) + 45$.

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?

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" ($14 \div 16$).

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- **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):**

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- 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 $(0.12 + 0.0765) = \mathbf{\$157.20}$.
 - 2. Calculate Net Pay (Take-home): $800 - 157.20 - \mathbf{45}$.
 - **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.
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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 Silvacrite 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 PHC work.
- **The Procedure:** Create a checklist for a hypothetical WBL site:

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- **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."*

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Appendix

[Link to NABCEP Solar Thermal Strands](#)

[Link to CTECS Licensed Trade VOG Guides & Resources](#)

[Link to Instructional Guidebook Resources](#)

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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:

Grade 9 Math Connection Master Review Table

| Priority Standard | Trade Topic | Primary Math Application | Core Formula / Code Reference |
|--|----------------------|--|---|
| 9.1: Shop and Site Safety | Ladder Safety | Calculating the 4:1 safety ratio for extension ladders to ensure a stable climbing angle. | Ratio: $\text{Height} \div 4 = \text{Base}$ |
| 9.2: Licensing & Procedure | Apprenticeship Hours | Calculating total required "Related Instruction" and "On-the-Job Training" hours for P-2 or S-4 licensing. | Addition: Summing hours over 4 years |
| 9.3: Basic Math & Sketching | Blueprint Scaling | Using an architectural scale to convert paper measurements into actual installation lengths for pipe runs. | Scaling: $1/4" = 1'0"$ or $1/8" = 1'0"$ |
| 9.4: Plumbing Codes | Minimum Clearances | Measuring and maintaining specific code-required distances for residential "rough-in" installations. | Linear Measurement: Fractions to $1/16"$ |
| 9.5: Hand Tool Usage | Precision Cutting | Determining "End-to-End" vs. "Center-to-Center" measurements when using saws and tubing cutters. | Subtraction: Total Length – Fitting Take-off |
| 9.6: Joining Pipe | Fitting Allowances | Calculating the depth of a pipe "socket" or "thread" to ensure | Geometry: Adding socket depths to the laying length |

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| | | accurate assembly of copper, PVC, or steel systems. | |
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Visualizing the 9th Grade Trade Math

- **Measurement Tip:** In the plumbing trade, a $1/8$ " error can cause a drain to lose its required "pitch," leading to clogs.
 - Grade 9 students must master reading a rule to the $1/16$ ".
- **Blueprint Tip:** Students learn that a line measuring 2 inches on a $1/4$ " scale plan actually represents 8 feet of physical pipe in the building.
- **Calculation Tip:** To cut a pipe to the correct length, students must subtract the "fitting allowance" (the distance from the center of the fitting to the start of the pipe) from their total measurement.

Student "Quick-Check" Challenges

1. **The Ladder Challenge:** You need to reach a roof line that is 16 feet high. How many feet away from the wall should you place the feet of your ladder? (Answer: **4 feet**).
2. **The Scaling Challenge:** On a $1/8" = 1'0"$ blueprint, a bathroom wall measures 1.5 inches. How long is the actual wall? (Answer: **12 feet**).
3. **The Hours Challenge:** If a student completes 180 hours of related instruction (RI) each year, how many total RI hours toward their P-2 license will they have after 4 years? (Answer: **720 hours**).

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CTECS Plumbing, Heating & Cooling Grade 10 Math/Trade Crossover

The math in Grade 10 shifts from simple linear measurement to **applied science**, where students calculate the relationship between water, pressure, and fixture requirements using the **International Plumbing Code (IPC)** and **International Residential Code (IRC)**.

Grade 10 Math Connection Master Review Table

| Priority Standard | Trade Topic | Primary Math Application | Core Formula / Code Reference |
|--|----------------------|--|--|
| 10.2: Piping Systems | Solar Thermal Piping | Calculating pipe expansion and contraction over long runs due to high-temperature solar fluids. | Coefficient of Thermal Expansion |
| 10.3: Plumbing Math & Science | Pressure & Force | Calculating the weight of water in a system and the pressure (PSI) exerted at the base of a vertical stack. | 1 foot of head = .433 PSI |
| 10.4: Pumping Systems | Pump Curves | Using X-Y axis graphs to plot "Head Pressure" against "Gallons Per Minute" (GPM) to select the correct circulator. | Manufacturer Pump Performance Curves |
| 10.5: Residential Fixtures | ADA Clearances | Calculating floor space and mounting heights for ADA-compliant water closets and lavatories. | IPC Chapter 4 / ICC A117.1 |
| 10.7: Blueprint Reading | Rough-in Dimensions | Interpreting "Rough-in Sheets" to determine the exact center-line of a drain based on finished wall thickness. | Addition/Subtraction of Finished Wall Material |

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| 10.8: Repair & Service | Thermal Efficiency | Comparing the fuel consumption and "Energy Factor" (EF) of high-efficiency vs. standard water heaters. | Percentage of Efficiency (%) |
|-----------------------------------|--------------------|--|------------------------------|

Visualizing the Grade 10 Trade Math

- **Science Tip:** In Grade 10, students learn that water "wants" to push down. For every **1 foot** they go up in a building, they need to overcome **0.433 PSI** of pressure.
- **Code Tip (Standard 10.5):** Students use the IPC to ensure a wheelchair can perform a **60-inch** "U-turn" in a bathroom. This is where geometry meets life-safety.
- **Pumping Tip (Standard 10.4):** Selecting a pump is not a guess. Students must calculate the **Total Dynamic Head** (friction loss) of the pipe and then find the intersection point on the manufacturer's curve.

Student "Quick-Check" Challenges

1. **The Head Pressure Challenge:** A water tank is located on the roof, 50 feet above the basement faucet. What is the static pressure at that faucet? (Calculation: $50 \times 0.433 = 21.65$ **PSI**).
2. **The ADA Clearance Challenge:** According to the ADA standards in your curriculum, how high must the seat of a toilet be from the floor? (Reference IPC/ADA: **17 to 19 inches**).
3. **The Rough-in Challenge:** A toilet requires a **12-inch** rough-in from the *finished* wall. If you are currently at the *stud* wall and adding 1/2" drywall and 1/4" tile, what is your rough-in measurement from the stud? (Calculation: $12 + 0.5 + 0.25 = 12.75$ **inches**).

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CTECS Plumbing, Heating & Cooling Grade 11 Math/Trade Crossover

The CTECS 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 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) |

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| 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 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: $\text{Area} \times \text{U-Value} \times \text{D T} = \text{Heat Loss}$. Important Note to ensure student 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 (DT) is 70°F, how many BTUs per hour are lost through that glass? (Calculation: $100 \times 0.5 \times 70 = 3,500 \text{ BTU/hr.}$)

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- 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**).
- 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**).

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Grade 12 Math/Trade Crossover

In Grade 12, the **CTECS 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) |

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| 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 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 = 2.77" w.c.) 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" w.c. at the manifold. If your manometer reads 0.2 PSI, is the pressure too high or too low? (Calculation: $0.2 \times 27.7 = 5.54$ " w.c. **Too High**).

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- The Static Pressure Challenge:** You measure a Return Static of $-0.2''$ w.c. 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.).

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