HVAC EFFICIENCY ANALYST **SENIOR CERTIFICATION**

Certification Information

Scope - Tests a candidate's knowledge of the installation, service, maintenance, and repair of HVAC system operations to maintain high levels of energy efficiency. System sizes are limited to 10 tons or less of Air Conditioning and 325,000 BTU or less heating capacity.

Qualifications

- This is a test and certification for **TECHNICIANS** in the HVAC industry. The test is designed for the highest level senior technician. This test for certification is not intended for the HVAC system designer, sales force, or the engineering community.
- This test will measure what 80% of the **HVAC Efficiency Analyst** candidates have an 80% likelihood of encountering at least once during the year on a **NATIONAL** basis.
- As a pre-requisite to sit for the **HVAC Efficiency Analyst** exam, the candidate shall hold two (2) certifications by NATE in Service Sector Specialties as follows:
    - Air Conditioning (AC) plus one of the following: AD, GS, OL, HG, or HO
    - Air Distribution (AD) plus one of the following: AC, GS, HP, OL, HG, or HO
    - Gas Heating (GS) plus one of the following: AC, AD, or HP
    - Heat Pump (HP) plus one of the following: AD, GS, OL, HG, or HO
    - Oil Heating (OL) plus one of the following: AC, AD, HP, HG, or HO
    - Hydronics Gas (HG) plus one of the following: AC, AD, or HP
    - Hydronics Oil (HO) plus one of the following: AC, AD, or HP

Test Specifications

Open Book **4 Hour Time Limit** **100 Questions** **Passing Score: PASS/FAIL**

Listed below are the percentages of questions that will be in each section of the **HVAC Efficiency Analyst** exam.

SECTION AREA DESCRIPTION	SECTION PERCENTAGE
Load Calculation	15%
Equipment Selection	10%
Air Distribution	20%
Hydronic Distribution	7%
System Performance	35%
Indoor Air/Environment Quality	7%
Planned Maintenance	6%

HVAC Efficiency Analyst Industry References

The reference materials listed below will be helpful in preparing for this exam. These materials may **NOT** contain all of the information necessary to be competent in this specialty or to pass the exam.

- Duct Calculators – Sheet Metal, Ductboard, and Flexible Duct
- American National Standards Institute (ANSI) / Air Conditioning Contractors of America (ACCA) Manuals - Latest Edition
    - "D", "J", "QI" - Quality Installation, and "S"
- ACCA Manuals "T" and "RS" - Latest Editions
- ACCA Residential Duct Diagnostics and Repair
- American National Standards Institute (ANSI) / Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA) Manuals
    - HVAC Duct Construction Standards - Metal and Flexible
- Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA) Manuals
    - Fibrous Glass Duct Construction Standards, Residential Comfort System Installation Standards Manual, and HVAC Air Duct Leakage Test Manual
- International Energy Conservation Code - Latest Edition with Addendum
- Air Diffusion Council Flexible Duct Performance & Installation Standards
- North American Insulation Manufacturers Association (NAIMA) Manuals
    - Fibrous Glass Duct Construction Standards and A Guide to Insulated Air Duct Systems
- International Mechanical Code - Latest Edition with Addendum
- International Fuel Gas Code – Latest Edition with Addendum
- National Fuel Gas Code – Latest Edition with Addendum
- Specification of Energy-Efficient Installation and Maintenance Practices for Residential HVAC Systems developed by Consortium for Energy Efficiency (CEE) - Latest Edition with Addendum
- ASHRAE Standard-62.2 - Latest Edition with Addendum
- ANSI / ASHRAE Standard-152-2004 - Latest Edition with Addendum
- ENERGY STAR™ Home Sealing Standards - Latest Edition with Addendum

Passing Score Development Process

The passing scores for the NATE tests were established using a systematic procedure (a Passing Score Study). This procedure employed the judgment of experienced HVAC professionals and educators representing various HVAC specialties and geographical areas. The passing scores were set using criteria defining competent performance. The passing score for different test forms may vary slightly due to the comparative difficulty of the test questions.

Exam Copyrights

Suggested Retail Price: $300

HVAC Efficiency

Senior

LOAD CALCULATION

CUSTOMER SURVEY

WEATHER DATA

- **Design temperature - summer**
- **Design temperature - winter**
- **Heating degree days**
- **Cooling degree days**
- **Equivalent full load hours**

BUILDING ORIENTATION

- **Building orientation**

BUILDING SETTING OPTIONS

- **On slab construction**
- **Crawlspace**
- **Partial basement (cellar)**
- **Full basement**

TAKE OFFS - BLUEPRINT OR ACTUAL SITE REVIEW

- **Construction of walls**
- **Area of walls**
- **Insulation of walls**
- **Number of windows (fenestration)**
- **Area of windows (fenestration)**
- **Construction of windows (fenestration)**
- **Orientation of windows (fenestration)**
- **Shading of windows (fenestration)**
- **NFRC window ratings (thermal effectiveness)**
- **Construction of floors**
- **Area of floors**
- **Insulation of floors**
- **Construction of ceilings**
- **Area of ceilings**
- **Insulation of ceilings**
- **Construction of roof**
- **Area of roof**
- **Insulation of roof**
- **Construction of skylight(s)**
- **Area of skylight(s)**
- **Thermal effectiveness of skylight(s)**

COORDINATION W/ ARCHITECT/DESIGNER/BUILDER/OTHER

- **Developing a good system design plan**
- **Ensuring good practices amongst the trades**

ZONING

SINGLE ZONE

- **Ducted**
- **Hydronic**

MULTIPLE ZONES

- **Ducted**
- **Hydronic**

INFILTRATION

AIR CHANGES PER HOUR

- **Equal exchange requirements**
- **Heat gain / loss per CFM**
- **Latent loss / gain per CFM**
- **Building assembly air leakage - normal / tight**

OCCUPANCY STANDARDS

- **Code requirements per occupancy**

EQUIPMENT REQUIREMENTS
- **Combustion air**
- **Ventilation air**
- **Dilution air**

DIAGNOSTIC TOOLS
- **Envelope pressurization test (blower door)**
- **Duct leakage test (duct blaster)**

HOME SEALING
- **Standards**
- **Requirements**

EXFILTRATION - EXHAUST REQUIREMENTS

OCCUPANCY STANDARDS
- **Code requirements per occupancy**

EQUIPMENT REQUIREMENTS
- **Boiler / furnace venting requirements**
- **Combustion air zone requirements**

VENTILATION

HEAT RECOVERY VENTILATOR (HRV)
- **Heat Recovery Ventilator (HRV)**

ENERGY RECOVERY VENTILATOR (ERV)
- **Energy Recovery Ventilator (ERV)**

INTERNAL LOADS
- **Human occupancy**
- **Equipment loads**

HEAT LOSS

TOTAL
- **Total**

SENSIBLE
- **Sensible**

LATENT
- **Latent**

HEAT GAIN

TOTAL
- **Total**

SENSIBLE
- **Sensible**

LATENT
- **Latent**

DUCT LOADS

GAIN
- **Total**
- **Sensible**
- **Latent**
- **Infiltration**

LOSS
- **Total**
- **Sensible**
- **Latent**
- **Infiltration**

DUCT DESIGN LOSS
- **Efficiency impact**
- **Comfort impact**
- **Improper duct design impact**
- **Improper duct installation impact**
- **Improper duct location impact**

REGULATIONS

INDOOR AIR QUALITY
- **Fresh air supplies**

CODES

CODES

- **Energy**
- **Plumbing**
- **Mechanical**
- **Fire**
- **Municipalities**

DESIGN CONSIDERATIONS - COMFORT

TEMPERATURE

- **Designing for capacity**
- **Using standard**

HUMIDITY

- **Role of humidity in total comfort**
- **Using standards**
- **Humidity control related to cooling equipment size (over-sizing)**

INDOOR AIR QUALITY

- **Ventilation - total comfort**
- **Air cleaning for total comfort**
- **Standards for air quality**
- **Outside air**
- **Filter ratings (MERV) related to system efficiency**
- **Filter effect on system efficiency related to static pressure during load calculation**

SOUND LEVEL

- **Equipment location considerations**
- **Isolation, mounting pad, duct, and structure**
- **Duct systems - flex joints**

ZONING

- **Single zone**
- **Multi-zone**

DESIGN CONSIDERATIONS - RESIDENTIAL

SPLIT SYSTEMS

- **Ventilation - fresh air**
- **Ventilation - equipment**

AIR BALANCING

- **Duct sizing**
- **Blower speed adjustments**
- **Damper position adjustments**
- **Estimated air-flow rate for proper capacity**

HYDRONIC BALANCING

- **Pipe sizing**
- **Pump speed adjustments**
- **Flow control position adjustments**
- **Estimated flow rate for capacity**

DESIGN CONSIDERATIONS - COMPONENTS

IMPACT OF DIFFUSERS, GRILLES, & REGISTERS

- **Energy use**
- **Comfort**
- **Temperature stratification**

IMPACT OF TEMPERATURE STRATIFICATION

- **Energy use**
- **Comfort**

IMPACT OF DIFF., GRILLES, & REGISTERS ON VSM'S

SELECTING DIFFUSERS FOR ENERGY EFFICIENCY

- **Selecting diffusers for capacity**
- **Selecting diffusers for reduced sound**
- **Selecting diffusers for spread, throw, and pressure drop**
- **Locations**

SELECTING GRILLES FOR ENERGY EFFICIENCY

- Selecting grilles for capacity
- Selecting grilles for reduced sound
- Selecting location

SELECTING REGISTERS FOR ENERGY EFFICIENCY

- Selecting registers for capacity
- Selecting registers for reduced sound
- Selecting registers for spread, throw, and pressure drop
- Locations
- Impact of registers on temperature stratification and energy use

DUCTS & FITTINGS - IMPACT ON ENERGY USE

- Specifying physical dimensions
- Sketching duct layout
- Duct fitting equivalency - Equivalent Length to duct size

SPECIAL DUCTS & FITTINGS

- Working drawings vs. Isometric drawings
- Markings and abbreviations for duct fitting and manufacturing
- Measurement for replacement of special duct or fitting

STATIC PRESSURE LOSSES

- Energy impacts of fan motors with variable speed
- Energy impacts on PSC fan motors
- Filter grilles
- Electronic Air Cleaner (EAC)
- Electrostatic
- Media type filters
- Use of alerts / reminders to change filters

SELECTING HYDRONIC COMPONENTS

- Selecting radiant output devices
- Selecting different in-floor configurations
- Selecting boiler temperature control devices
- Selecting valves based on pressure drop / capacity
- Selecting coils by capacity
- Selecting pumps
- Selecting pipe insulation
- Selecting other distribution devices (hydronic specialties)

BLUEPRINT READING

- Determination of dimension from scale blueprint / plans
- Reading blueprints / plans
- Visualizing duct layout from blueprints / plans

MECHANICAL CODE

EQUIPMENT ACCESS

- Minimum clearance
- Electrical disconnects
- Fire dampers

REFRIGERANT LINE ROUTING

- Support requirements
- Inspection requirements

CONDENSATE DRAINS

- Materials
- Sizing
- Location and routing
- Clean outs and cut-offs

INDUSTRY STANDARDS

EQUIPMENT STANDARDS

- Introduction to industry standards
- ARI standards for ratings

SYSTEM STANDARDS

- Introduction to industry standards
- ASHRAE standards
- SMACNA standards

- **ACCA standards**
- **CEE specification**

DESIGN CONSIDERATIONS - LIGHT COMMERCIAL

SPLIT SYSTEMS

- **System designs - closets, basements, etc.**
- **Air distribution systems**
- **Ventilation - fresh air**
- **Ventilation - equipment**

PACKAGED SYSTEMS

- **System designs**
- **Economizers**
- **Ventilation - equipment**

AIR BALANCING

- **Duct sizing**
- **Blower speed adjustments**
- **Damper position adjustments**
- **Measurement of air flow rate**
- **Fan laws**

DESIGN CONSIDERATIONS - INCORRECT LOAD

CONSEQUENCES OF UNDER-SIZING

CONSEQUENCES OF OVER-SIZING

BIDS AND PROPOSALS

SYSTEM SIZING

- **Survey of requirements**
- **Selecting equipment**
- **Selecting accessories**

PREPARATION FOR PROPOSAL

- **Understanding forms for proposals and bids**
- **Understanding legal implications of a bid**

EQUIPMENT SELECTION

CAPACITY

DESIGN HEATING LOAD

- **Total load**
- **Sensible load**
- **Latent load**
- **CFM / FPM Requirements**
- **GPM / PSI Requirements**
- **Ventilation requirements**
- **Matching of condenser and evaporator coil capacity - heat pumps**
- **Impacts of heat recovery or energy recovery ventilators**
- **Impacts of over-sizing and/or under-sizing**

DESIGN COOLING LOAD

- **Total load**
- **Sensible load**
- **Latent load**
- **CFM / FPM Requirements**
- **GPM / PSI Requirements**
- **Ventilation requirements**
- **Impact of airflow on humidity removal**
- **Matching of condenser and evaporator coil capacity**
- **Use of thermostats to control humidity through airflow control**
- **Impacts of heat recovery or energy recovery ventilators**
- **Impacts of over-sizing and/or under-sizing**

DESIGN VENTILATION LOAD

- **Total load**
- **Sensible load**
- **Latent load**
- **CFM / FPM Requirements**

- Ventilation requirements - natural / mechanical
- Impact of airflow on humidity removal
- Use of controls for humidity through airflow control
- Impacts of heat recovery or energy recovery ventilators
- Impacts of over-sizing and/or under-sizing
- Impacts of night ventilation
- Impacts of attic ventilation
- Impacts of evaporative coolers

EFFICIENCY

SYSTEM EFFICIENCY

- Steady state efficiency
- Define ducts inside conditioned space
- Ducts outside conditioned space
- Ducted system gains / losses
- Hydronic system gains / losses

HEATING EFFICIENCY

- Gas furnace / boiler - Annual Fuel Utilization Efficiency (AFUE)
- Efficiency gains with condensing furnaces vs. 80%
- Comfort / efficiency gains with variable speed blower systems
- Comfort / efficiency gains with two stage heating
- Discussion of reduced comfort / efficiency of over-sizing heating systems
- Impact of furnace fan
- Oil furnace / boiler - combustion efficiency
- Electric furnace / boiler efficiency

COOLING EFFICIENCY

- Seasonal Energy Efficiency Ratio (SEER)
- Importance of coil selection on efficiency and capacity (sensible/latent)
- Energy Efficiency Ratio (EER)
- Impact of furnace fan

CAPACITY CONTROLS

AIR DISTRIBUTION SYSTEM

- Constant fan speed selection - 1, 2, 3, 4
- Variable fan speed selection
- Thermostat control
- CFM selection for humidity removal
- Constant CFM per ton
- Zoning control system

WATER DISTRIBUTION SYSTEM

- Constant pump speed selection
- Variable pump speed selection
- Zoning control system - valves or pumps

BOILER / FURNACE COMPONENTS

- Constant firing rates
- Variable firing rates
- Electrical sequencing
- Flow controls

COOLING COMPONENTS

- Single compressor
- Dual speed compressors
- Unloading compressors
- Multiple compressors
- Variable speed compressors
- Metering devices

LOW AMBIENT CONTROLS

HEATING

- Outdoor reset control
- Electric heating element sequencing
- Electric heating element lockout

COOLING

- Variable condenser fan operation
- On / off condenser fan
- Two-stage air conditioner with variable speed fan
- Bypass

AIR DISTRIBUTION

SYSTEMS AND COMPONENTS

HEAT TRANSFER AND THE HEATING / COOLING CYCLE

- Heat transfer and cooling
- Refrigeration circuit - components
- Dynamic analysis of temperatures and pressure in the refrigerant circuit.
- Psychrometrics
- Subcooling
- Superheat

DUCT SYSTEMS

IMPACT ON ENERGY USE OF BASIC DUCT SYSTEMS

- Overview of duct systems for split and package systems
- Duct configuration - extended plenum
- Duct configuration - reducing extended plenum
- Duct configuration - perimeter radial
- Duct configuration - perimeter loop
- Duct configuration - overhead radial
- Duct configuration - branching flexible
- Duct configuration - concentric

IMPACT ON ENERGY USE OF DUCT LOCATION

- Attic
- Basement
- Crawlspace
- Slab
- Roof
- Furred down
- Exposed
- Chases
- Inside the envelope - avoid non-insulated areas

BASIC ZONE SYSTEMS

- Equipment zoned
- Air side zoned

IMPACT ON ENERGY USE OF DUCT MATERIALS

- Define / recognize ductboard
- Define / recognize metal duct
- Define / recognize flexible duct
- Define / recognize PVC pipe
- Insulating material

FITTING NOMENCLATURE

- Define / recognize plenum
- Define / recognize transition
- Define / recognize elbow - 90 degrees and 45 degrees
- Define / recognize round duct
- Define / recognize rectangular duct
- Define / recognize turning vanes
- Return configurations - ducted, central, etc.
- Define / recognize wye - rectangular and round
- Define / recognize damper - rectangular and round
- Sheet metal duct joints - "s" and drive, snaplock, button lock, etc.

IMPACT ON ENERGY USE OF DAMPERS

- Balancing
- Splitters
- Economizers
- Fresh air
- Fire

GRILLES

- Types and uses
- Selecting grilles by volume and velocity
- Selecting grilles by purpose (floor, wall, and ceiling)
- Proper installation techniques (follow installation instructions)

IMPACT ON ENERGY USE OF REGISTERS

- Types and uses
- Selecting registers
- Selecting registers by use of fan specifications
- Selecting registers by air spread and throw capacity
- Proper installation techniques (follow installation instructions)

DIFFUSERS

- Types and uses
- Selecting diffusers
- Selecting diffusers by use of fan specifications
- Selecting diffusers by air spread and throw capacity
- Proper installation techniques (follow installation instructions)

IMPACT ON ENERGY USE OF FILTRATION SYSTEMS

- Filter access closures system
- Media type filters
- Electronic Air Cleaner (EAC)
- Electrostatic filters - non-electric
- Static pressure increases energy by ECM fan motors

VENTILATION SYSTEMS

- Depressurization criteria
- Draft of conditioned air into non-conditioned areas
- Pressurization criteria
- Forcing conditioned air into non-conditioned areas
- Attic exhaust
- Residential exhaust(s)
- Lt. Commercial exhaust(s)
- Heat / energy recovery ventilators
- Infiltration
- Passive venting
- Soffits vents
- Ridge vents
- Gable vents
- Power venting

HUMIDIFIERS

- Fundamentals of operation
- Types
- Duct material requirements
- Installation support
- Installation location(s)

DUCT FABRICATION

DUCT FABRICATION EQUIPMENT

- Ductboard tools - 90 V-groove, end cutoff, female shiplap, hole cutter, stapler, etc.
- Flex tools - tensioning strap tools, knives, etc.
- Metal tools - metal snips, sheers, benders, breaks, hand formers, calipers, rulers, stapler, etc. -

FABRICATION TECHNIQUES FOR METAL DUCT

- Seam types - pittsburgh and snap lock
- Joint types - gasketed connectors (J or G), drive cleats, reinforced drive cleats, "s" slip, and standing "s" slip
- Use of strength breaks in rectangular duct

FABRICATION TECHNIQUES FOR DUCTBOARD

- Layout of duct fitting
- Groove cutting - hand / machine
- Proper use of joint tape
- Approved type of joint tape

- Foil faced
- Mastic type
- UL181

DUCT INSTALLATION

FIELD CONSTRUCTION / INSTALLATION
- Ductboard installation technique
- Techniques for joining dissimilar duct
- Duct of alternate materials - wood, aluminum, etc.

INSTALLING METAL DUCT
- Assembly methods for rectangular duct
- Installation technique - rectangular metal
- Assembly methods for round duct
- Installation technique - round metal
- Hanging ductwork
- Sealing metal duct
- Insulation - internal and external

INSTALLING FLEXIBLE DUCT
- Assembly methods
- Appropriate length
- Follow installation instructions
- Flexible duct joints
- Hanging flexible duct
- Allowed deflection
- Unacceptable deflection
- Installation technique - flex duct
- Sealing flexible duct

INSTALLING DUCTBOARD
- Assembly methods for ductboard - supports
- Installation technique -ductboard
- Hanging methods for ductboard
- Sealing ductboard

DUCT SEALING MATERIALS
- Duct mastic
- Approved tapes

INSTALL. GRILLE, REGISTER, DIFFUSER, & DAMPER
- Mounting to ductwork
- Securing methods

CHASES USED AS DUCTS
- Floor joists as air ducts
- Vertical chases
- Floor joists as air ducts - impact on energy use
- Vertical chases - impact on energy use

RECONNECTING DUCT WHEN REPLACING EQUIPMENT
- Reconnecting metal duct
- Reconnecting flexible duct
- Reconnecting ductboard duct

INSTALLATION OF PLENUMS AND DUCT
- Sizing plenums for physical fit
- Types and styles of plenums selected for oil furnace
- Insulation of plenums and ducts

AIRFLOW PRINCIPLES

AIRFLOW
- Velocity
- Static pressure
- Airflow volume - CFM / SCFM (Standard Air CFM)

BLOWERS AND FANS
- Define sequence of operation
- Air side requirements

AIRFLOW MEASUREMENTS

TOOLS

- Using temperatures to determine airflow
- Using manufacturer's airflow charts and/or tables
- Measuring total supply and return airflow

AIRFLOW VELOCITY MEASUREMENTS

- Pitot tube and manometer in measuring static pressure
- Discharge velocity equipment
- Static pressure drop across evaporator coil
- Fan laws using known static pressure drop at specific flow(s)
- Velometer - electronic and mechanical
- Anemometer
- Velocity measurement procedures
- Gauge calibration
- Airflow
- Velocity

AIRFLOW PRESSURE MEASUREMENTS

- Overview of static pressure measurements
- Inclined manometer
- Diaphragm type differential pressure gauge
- U-tube manometer
- Electronic manometer / pressure measurement
- Gauge / meter calibration
- Absolute vs. Gauge Pressure
- Static pressure
- Air pressure measurement terminology
- Velocity pressure
- Total pressure

AIR VOLUME MEASUREMENTS

- Airflow hood
- Formulae for determining CFM of air
- Formulae for weight of air
- Locations for air volume measurements
- Airflow volume - CFM / SCFM (Standard Air CFM)
- Powered flow hood test
- Flow plate

DUCT LEAKAGE MEASUREMENTS (ALLOWANCE)

- Duct leakage allowance to outdoors
- Duct leakage allowance from outdoors
- Duct leakage allowance to ambient
- Duct leakage allowance from ambient
- Total duct leakage allowance

AIR BALANCING

GATHERING DESIGN INFORMATION

- Interpreting plans
- Interpreting specifications
- Interpreting equipment information
- Interpreting control data
- Interpreting as-built plans

PREPARATION OF SYSTEM FOR AIR TESTS

- Locating registers, grilles, equipment, controls, and dampers in building walk-through
- Setting dampers for tests
- Setting thermostat for tests
- Checking for proper fan operation and rotation
- Checking for proper static pressure and temperature

PROCEDURES FOR CONDUCTING AIR TESTS

- Measurements of each supply outlet - total readings
- Measurements of each return inlet - total readings

MAKING ADJUSTMENTS

Adjust airflow to achieve required total airflow
Re-measure total supply and return grille airflow
Adjust dampers to obtain design airflow
Re-measure total airflow to verify that it is within specification

FINAL TEST

Comparing manufacturer's equipment information with test results
Record sheave, pulley, and belt sizes data
Test and record full load motor amperes
Test and record voltage
Test and record motor and fan RPM
Test and record supply and return static pressures
Test and record supply and return air temperatures - wet bulb and dry bulb

COMPLETION OF APPROPRIATE FORMS

HVAC system report
System diagrams
Duct traverse or data pulley forms
Instrument list - including calibration dates

HVAC SYSTEM ANALYSIS

NOISE PROBLEMS

Interpreting supply / return air volume
Interpreting supply / return air velocity
Noise problems
Blower cavitation
Oil canning
Motor / belt noise
Vibration

HIGH UTILITY BILLS

Understanding of utility bills – interpreting energy usage
Assess customer practices or characteristics impacting energy use

WIDE TEMPERATURE SWINGS

Interpreting supply / return air temperature
Interpreting supply / return air volume
Evaluating duct leakage
Evaluating duct insulation
Envelope evaluation
Thermostat air sensing
Assess thermal reasons for temperature stratification
Understanding system interactions
Locational impact of supply registers and return
Evaluating throw and/or velocity

SINGLE/MULTIPLE AREA IS HOT OR COLD

Interpreting supply / return air temperature
Interpreting supply / return air volume
Evaluating duct leakage
Evaluating duct insulation
Envelope evaluation
Thermostat air sensing
Understanding system interactions
Locational impact of supply registers and return
Evaluating throw and/or velocity

INDOOR AIR QUALITY

Number of air changes per hour
Source control
Assess fan operation (ex. continuous)
Type of filter
Filter maintenance practices
Humidity or mold issues

ANALYZING REPORTED SYMPTOMS IN COOLING

POOR COOLING

Interpreting supply / return air temperature
Interpreting supply / return air volume
Interpreting supply / return air velocity
Determining and interpreting the sensible heat ratio
Evaluating duct leakage
Evaluating envelope infiltration
Using wet bulb temperature drop across evaporator coil

HUMIDITY PROBLEMS

Interpreting wet bulb and dry bulb temperatures
Interpreting supply / return air volume
Determining and interpreting the sensible heat ratio
Evaluating duct leakage
Evaluating envelope infiltration

DRAFTY

Assess return and supply issues
Interpreting supply / return air temperature
Interpreting supply / return air volume
Interpreting supply / return air velocity
Evaluating envelope infiltration

ANALYZING REPORTED SYMPTOMS IN HEATING

POOR HEATING

Interpreting supply / return air temperature
Interpreting supply / return air volume
Interpreting supply / return air velocity
Evaluating duct leakage
Using temperature rise across the heat exchanger

HUMIDITY PROBLEMS

Interpreting wet bulb and dry bulb temperatures
Interpreting supply / return air volume
Determining the need for additional humidity
Evaluating duct leakage

DRAFTY

Interpreting supply / return air temperature
Interpreting supply / return air volume
Interpreting supply / return air velocity

DEALING WITH CONFLICTS

CODES

Codes vs. standards

STANDARDS

Standards vs. codes

BUILDING SCIENCE

Building science vs. codes or standards

HYDRONICS DISTRIBUTION

HEATING COMPONENTS

PROPER SELECTION

Baseboard units (finned, cast, radiant, etc.)
Kickspace heaters
Types of unit heaters
Radiant ceiling heating or cooling panels
Duct mounted heating coils
Hot water coil air handlers
Circulation pumps
Sizing of zoning distribution
Placement and location of types of heating units
Placement of air vents (manual or auto)
Radiant floor heating – how to maximize comfort with proper insulation with installation

PROPER SIZING

Baseboard units (finned, cast, radiant, etc.)

- Kickspace heaters
- Types of unit heaters
- Radiant ceiling heating or cooling panels
- Duct mounted heating coils
- Hot water coil air handlers
- Circulation pumps
- Sizing of zoning distribution
- Placement and location of types of heating units
- Placement of air vents (manual or auto)
- Radiant floor heating – how to maximize comfort with proper insulation with installation

PROPER INSTALLATION

- Baseboard units (finned, cast, radiant, etc.)
- Kickspace heaters
- Types of unit heaters
- Radiant ceiling heating or cooling panels
- Duct mounted heating coils
- Hot water coil air handlers
- Circulation pumps
- Sizing of zoning distribution
- Placement and location of types of heating units
- Placement of air vents (manual or auto)
- Radiant floor heating – how to maximize comfort with proper insulation with installation

AUXILLARY COMPONENTS

- Location and selection of circulators
- Location and sizing of expansion tanks
- Location of air separators
- Location of pressure reducing valve
- Location of backflow preventer
- Location and sizing of relief valves
- Location of zone valves
- Location of flow check devices
- Location of water treatment access
- Installation of indirect water heaters
- Installation of low water cutoffs

PIPING SYSTEMS

- Installation of series-loop system (benefits and limitations)
- Installation of one-pipe system (benefits and limitations)
- Installation of two-pipe system (reverse return) (benefits and limitations)
- Installation of primary / secondary piping system (benefits and limitations)
- Installation of multiple zone systems (benefits and limitations)
- Installation of system bypass and boiler bypass piping
- Installation of boiler piping (near, manifold piping, hartford loop)

WATER MEASUREMENTS

- Pressure requirements
- GPM requirement
- Temperature drop

INSTALLING THERMOSTATS

- Locating and mounting
- Wiring electromechanical thermostats
- Wiring electronic thermostats
- Programming of electronic thermostats
- Installation of outdoor reset controls

SYSTEM PERFORMANCE

GAS HEATING

COMPONENTS

- Define heat exchanger
- Define limit controls
- Define vent system
- Define burners

- Define fan controls
- Define gas valve
- Combustion air proving (pressure) switch
- Hydronic controls

OPERATION

- Define combustion air system
- Air side requirements
- Wet side requirements
- Define sequence of operation

OIL HEATING

COMPONENTS

- Define heat exchanger
- Define limit controls
- Define vent system
- Define oil burners
- Retention head burners energy efficiency gains
- Hydronic controls

OPERATION

- Define combustion air system
- Air side requirements
- Wet side requirements
- Define sequence of operation

AIR CONDITIONING / HEAT PUMPS

COMPONENTS

- Define evaporator
- Define condenser
- Define compressor
- Define metering device
- Reversing valves
- Defrost controls

OPERATION

- Define sequence of operation
- Airside requirements
- Metering device performance

ELECTRONIC CONTROLS

ELECTRONIC CONTROLLERS

- Input / output operations
- Logic
- Electronic interface
- Tap boards

ELECTRONIC THERMOSTATS

- Selecting electronic thermostats
- Electronic thermostat operation

ZONE CONTROLS

- Selecting zone controls
- Typical zone control logic
- Bypass dampers
- Types of zone controls

ELECTRONIC COMPRESSOR CONTROLS

- Compressor staging controls
- Compressor time delays

ELECTRONIC TIMERS

- Blower delay timers

ECONOMIZER CONTROLLERS

- Dry bulb controllers
- Enthalpy controllers
- Potentiometers
- Sensors

ELECTROMECHANICAL SENSING CONTROLS

ELECTROMECHANICAL WALL THERMOSTATS

- Thermostat types and operation
- Thermostat terminals and wiring
- Selecting wall thermostats and sub-bases
- Using electromechanical thermostats

ELECTROMECHANICAL TEMPERATURE CONTROLS

- Bimetal controls
- Disc type temperature limit controls
- Electric heat high limits
- Fuses and fuse links
- Motor overloads
- Fossil fuel kits

PRESSURE CONTROLS

- Disc type pressure controls and hi/low controls
- Selection of disc type pressure controls
- Using disc type pressure controls
- Low ambient cooling controls

ELECTROMECHANICAL OUTDOOR THERMOSTATS

- Outdoor thermostats
- Outdoor thermostat wiring

TROUBLESHOOTING SEQUENCE OF OPERATION

- Check for proper sequence of operation
- Interpreting system at sequence interruption

ANALYZING REPORTED SYMPTOMS

- Insufficient / no heat
- Short cycle
- Humidity problems
- Drafty
- Noise problems
- System runs continuously
- High utility bills
- Wide swings in room temperatures
- Air quality
- Noisy conditions due to air in piping

SYSTEM AIR SIDE DIAGNOSTICS

- Temperature checks
- Check system static pressure
- Check system velocity

ELECTRICAL CIRCUIT CHECKS

- Supply voltage
- Indoor blowers
- Wall thermostat
- Transformers
- Electronic controllers - input / output
- Flame rectification
- Pilot ignition
- Thermocouple / power pile generator
- Fuel valve

ELECTRICAL COMPONENT CHECKS

- Thermostat
- Transformers
- Fuses and breakers
- Relays and contactors
- Capacitors
- Pressure controls
- Limit controls
- Centrifugal switch
- Door interlock switch

- Circulators
- Zone valves
- Boiler water controls (aquastats)

REPAIRS
- Electrical wiring
- Electrical components
- Fuel supply
- Flue stack / venting system
- Condensate / drain system

REPLACEMENTS
- Transformers
- Relays and contactors
- Indoor blowers
- Capacitors
- Heat exchanger
- Fuel valve
- Safety circuit switches
- Draft motor
- Pilot / igniters assemblies
- Flame sensing rod
- Circulators
- Zone valves
- Boiler water controls

VENT SYSTEM CHECKS
- Natural / gravity draft
- Forced draft
- Induced draft

DIAGNOSING COMBUSTION PROBLEMS
- Flame "roll-out"
- Flame "lift-off"
- Discolored flame
- Intermittent flame
- Partial burner flame
- Delayed ignition
- Carbon build up
- Flashback
- Trip on high limit
- Carbon Monoxide
- Carbon Dioxide checks for efficiency
- Interpreting a smoke test
- Balancing excess air and the smoke test
- Diagnosing air leaks and efficiency loss
- Diagnosing low draft-stack, overfire
- Diagnosing excessive draft-stack, overfire
- Diagnosing excessive draft on off cycle
- Interpreting steady state efficiency measurements - stack loss calculations
- Interpreting oxygen content for combustion diagnostics
- Duct leakage induced combustion venting problems
- Heating plants and water heaters
- Problems with / caused by attic fans

LOW VOLTAGE CIRCUITS
- Voltage tests
- Control string analysis
- Low voltage troubleshooting
- Troubleshooting equipment with electronic devices
- Troubleshooting with schematics
- Troubleshooting without schematics
- Current tests
- Equipment continuity tests

- Ground tests

LINE VOLTAGE CIRCUITS

- Voltage tests
- Current tests
- Component tests
- Circuit tracing line voltages
- Troubleshooting with schematics
- Troubleshooting without schematics
- Equipment continuity tests
- Ground tests

FUEL PRESSURE MEASUREMENTS

- Manometer
- Dial gauge

LEAK DETECTION - FUEL LINES

- Leak detection solution
- Electronic leak detectors

FLUE GAS ANALYSIS

- O2 measurements
- Carbon Dioxide measurements

LEAK DETECTION - FLUE PASSAGES

- Carbon Monoxide detector - electrical
- Carbon Monoxide detector - manual

NOISE PROBLEMS

- Interpreting supply / return air volume
- Interpreting supply / return air velocity
- Noise problems - air and water
- Blower and pump cavitation
- Oil canning
- Motor / belt noise
- Vibration

HIGH UTILITY BILLS

- Baseline utility expenses in relation to heating / cooling expenses
- Interpreting supply / return air and water temperature
- Interpreting supply / return air and water volume
- Interpreting supply / return air and water pressures
- Evaluating duct leakage
- Evaluating duct insulation
- Envelope insulation
- Envelope infiltration
- Thermostat air sensing

WIDE TEMPERATURE SWINGS

- Interpreting supply / return air and water temperature
- Interpreting supply / return air and water volume
- Interpreting supply / return air and water pressures
- Evaluating duct leakage
- Evaluating duct insulation
- Envelope insulation
- Envelope infiltration
- Thermostat air sensing

AREA(S) BEING HOT / COLD

- Interpreting supply / return air and water temperature (TD)
- Interpreting supply / return air and water volume
- Interpreting supply / return air and water pressures
- Evaluating duct leakage
- Evaluating duct insulation
- Envelope infiltration
- Envelope insulation
- Thermostat air sensing
- Zone controls - dampers and valves

- **Circulator(s)**
- **Blower(s)**
- **Circulator controls**
- **Outdoor reset control**
- **Evaporator coil temperature drop**

INDOOR AIR QUALITY

- **Number of air changes per hour**
- **Source control**
- **Economizer operations**

HUMIDITY PROBLEMS

- **Interpreting wet bulb and dry bulb temperatures**
- **Interpreting supply / return air volume**
- **Determining the need for additional humidity**
- **Evaluating duct leakage**
- **Evaluating envelope infiltration**

DRAFTS

- **Interpreting supply / return air temperature**
- **Interpreting supply / return air volume**
- **Interpreting supply / return air velocity**
- **Evaluating envelope infiltration**

REFRIGERANT SYSTEM DIAGNOSTICS

- **Using superheat**
- **Using subcooling**
- **Refrigerant charge specification**
- **Refrigerant charge adjustment**
- **Energy impacts of undercharging**
- **Energy impacts of overcharging**
- **Energy impacts of metering devices - TXV / fixed**
- **Analyzing overall refrigerant circuit performance**
- **Analyzing effects of refrigerant circuits on reversing valve operation**
- **Locating problems based on refrigerant circuit temperatures**

INDOOR AIR / ENVIRONMENT QUALITY

DESIGNING FOR ACCEPTABLE IAQ / IEQ

UNDERSTANDING VENTILATION AND ACCEPTABLE IAQ

- **Requirement for mechanical and natural ventilation**

INSTALLING IAQ / IEQ SYSTEMS

PREVENTING RE-ENTRAINMENT & CROSS-CONTAMINATION

OPERATING & MAINTAINING IAQ / IEQ SYSTEMS

FILTRATION SYSTEMS

RECOVERY VENTILATORS

ULTRAVIOLET C (UVC)

EXHAUST/VENTILATION FANS

TROUBLESHOOTING IAQ / IEQ SYSTEMS

REVIEW PLANS

CONDUCT INTERVIEWS

DIAGNOSTICS

DOCUMENT RESULTS

IAQ / IEQ CONTROL STRATEGIES

POLLUTANT PATHWAYS

- **Doors**
- **Windows**
- **Elevator shafts**
- **Chimneys**
- **Garages**
- **Plumbing stacks**
- **Stairs**
- **Ducts**
- **Chases**

- Basements
- **SOURCE CONTROL - REMOVE / CONTAIN**
  - Volatile Organic Compounds (VOC) - Formaldehyde, Ozone, Tobacco Smoke
  - Inorganic Compounds - NOx, Radon, CO, CO2
  - Moisture
  - Biological
- **FILTRATION**
  - Particulate
  - Gases
- **DILUTION AIR**
- **LOCAL EXHAUST**
  - Bathrooms
  - Kitchens
  - Copiers
- **WHOLE HOUSE VENTILATION**

PLANNED MAINTENANCE

- PLANNED MAINTENANCE
- **ELECTRICAL**
  - Connection checks
  - Control checks
  - General wiring
  - Induced draft motor
  - Forced draft motors
  - Supply air motor
  - Operation sequence
- **AIR DISTRIBUTION**
  - Fan blades / blower scroll
  - Diffusers, grilles, and registers
  - Lubrication of blowers
  - Coil cleaning
  - Filter cleaning / replacement
  - Duct leakage check
  - Velocity
  - Volume
- **HYDRONIC**
  - Pumps
  - Lubrication
  - Valves
  - Vents
  - Relief
  - Flow rates
  - Pressure
  - Expansion tank
  - Water treatment
  - Pump strainers
- **FIRE SIDE**
  - Oil burner assembly service
  - Sectional cleaning
  - Gas burner assembly service
  - Performance checks - heat exchanger temperature rise
  - Flue / vent stack inspections
  - Combustion air supply check and adjustment
  - Fuel supply connections
  - Sequence of operation checks
  - Air intake / exhaust
  - Flame
  - Ignition
  - CO test
  - Draft test

- CAZ Test

REFRIGERATION SYSTEM

- Using superheat
- Using subcooling
- Refrigerant charge specification
- Refrigerant charge adjustment
- Energy impacts of undercharging
- Energy impacts of overcharging
- Energy impacts of metering devices - TXV / fixed
- Analyzing overall refrigerant circuit performance
- Analyzing effects of refrigerant circuits on reversing valve operation
- Locating problems based on refrigerant circuit temperatures

$\frac{CFM_n}{CFM_o} = \frac{RPM_n}{RPM_o}$ o = old, n = new CFM and RPM are interchangeable. $CFM_n = CFM_o \times \frac{RPM_n}{RPM_o}$ $RPM_n = RPM_o \times \frac{CFM_n}{CFM_o}$

$\left(\frac{CFM_n}{CFM_o}\right)^2 = \frac{Sp_n}{Sp_o}$ OR $\frac{CFM_n}{CFM_o} = \sqrt{\frac{Sp_n}{Sp_o}}$ $CFM_n = CFM_o \times \sqrt{\frac{Sp_n}{Sp_o}}$ $Sp_n = Sp_o \times \left(\frac{CFM_n}{CFM_o}\right)^2$

$\left(\frac{CFM_n}{CFM_o}\right)^3 = \frac{BHP_n}{BHP_o}$ OR $\frac{CFM_n}{CFM_o} = \sqrt[3]{\frac{BHP_n}{BHP_o}}$ $CFM_n = CFM_o \times \sqrt[3]{\frac{BHP_n}{BHP_o}}$ $BHP_n = BHP_o \times \left(\frac{CFM_n}{CFM_o}\right)^3$

Hydronics: ΔP = Sp, CFM = GPM, RPM = GPM

$MAT = (OAT \times \%OA) + (RAT \times \%RA)$

O = Outside
T = Temperature
R = Return
M = Mixed
A = Air

Btuh hydronic (H_2O only) = 500 × GPM × ΔT
Btuh sensible (at sea level) = 1.08 × CFM × ΔT
Btuh latent (at sea level) = 0.68 × CFM × ΔGrains
Btuh total (at sea level) = 4.5 × CFM × ΔEnthalpy

$CFM = \frac{AC/Hr \times Volume}{60\ min}$ $V = 4005 \times \sqrt{Vp}$ $Vp = \left(\frac{V}{4005}\right)^2$

Pressure (PSI) = 0.433 × Head (feet of water)

1 IWC = 0.0360 PSI
1 PSI = 27.72 IWC

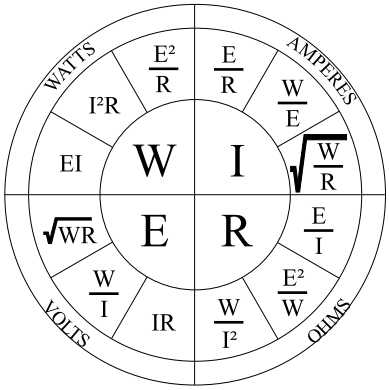
Pressure 1 × Volume 1 = Pressure 2 × Volume 2

$Area = \pi \times radius^2$

$A^2 + B^2 = C^2$

$Diameter = \frac{Circumference}{\pi}$

$FR = \frac{ASP \times 100}{TEL}$ *(IWC/100)*



Rectangular Duct Area (ft^2) = $\frac{Length \times Width}{144}$

Round Duct Area (ft^2) = $\frac{\pi \times diameter^2}{576}$

$mfd = \frac{(2650 \times I)}{E}$

CFM = Velocity (fpm) × Duct Area (ft^2)

$CFM = \frac{(Watts \times 3.413)}{(\Delta T \times 1.08)}$

C_T (Series) = $\frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_N}}$

C_T (Parallel) = $C_1 + C_2 + \ldots + C_N$

TEMPERATURE PRESSURE CHART – at sea level

Pressure (PSIG), Vacuum (in. Of Hg) – Bold Italic Figures
To determine subcooling for 404A, 407C, and 422D, use BUBBLE POINT values (temperatures above 50°F – gray background)
To determine superheat for 404A, 407C, and 422D, use DEW POINT values (temperatures 50°F and below)

TEMP.		REFRIGERANT						
°F	°C	22	134a	404A	407C	410A	422D	507
-40	-40.0	0.6	***14.8***	4.3	***4.6***	10.7	***2.3***	5.4
-38	-38.9	1.4	***13.9***	5.3	***3.2***	12.0	***0.8***	6.4
-36	-37.8	2.2	***13.0***	6.3	***1.6***	13.4	0.4	7.5
-34	-36.7	3.1	***12.0***	7.4	0.0	14.8	1.2	8.6
-32	-35.6	4.0	***10.9***	8.5	0.8	16.2	2.1	9.8
-30	-34.4	4.9	***9.8***	9.6	1.6	17.8	3.0	11.0
-28	-33.3	5.9	***8.7***	10.8	2.5	19.3	3.9	12.2
-26	-32.2	6.9	***7.5***	12.0	3.5	21.0	4.9	13.5
-24	-31.1	8.0	***6.3***	13.3	4.4	22.7	5.9	14.8
-22	-30.0	9.1	***5.0***	14.6	5.4	24.4	7.0	16.2
-20	-28.9	10.2	***3.7***	16.0	6.5	26.3	8.1	17.6
-18	-27.8	11.4	***2.3***	17.4	7.6	28.1	9.2	19.1
-16	-26.7	12.6	***0.8***	18.9	8.7	30.1	10.4	20.6
-14	-25.6	13.9	0.4	20.4	9.9	32.1	11.7	22.2
-12	-24.4	15.2	1.1	22.0	11.1	34.2	12.9	23.8
-10	-23.3	16.5	1.9	23.6	12.3	36.4	14.3	25.5
-8	-22.2	17.9	2.8	25.3	13.7	38.6	15.6	27.3
-6	-21.1	19.4	3.6	27.0	15.0	40.9	17.1	29.1
-4	-20.0	20.9	4.6	28.8	16.4	43.3	18.5	30.9
-2	-18.9	22.4	5.5	30.7	17.9	45.8	20.1	32.8
0	-17.8	24.0	6.5	32.6	19.4	48.3	21.6	34.8
1	-17.2	24.9	7.0	33.6	20.2	49.6	22.5	35.8
2	-16.7	25.7	7.5	34.6	21.0	51.0	23.3	36.9
3	-16.1	26.5	8.0	35.6	21.8	52.3	24.1	37.9
4	-15.6	27.4	8.5	36.6	22.6	53.7	25.0	39.0
5	-15.0	28.3	9.1	37.7	23.5	55.0	25.8	40.0
6	-14.4	29.2	9.6	38.7	24.3	56.5	26.7	41.1
7	-13.9	30.1	10.2	39.8	25.2	57.9	27.6	42.2
8	-13.3	31.0	10.8	40.9	26.1	59.3	28.5	43.4
9	-12.8	31.9	11.3	42.0	27.0	60.8	29.5	44.5
10	-12.2	32.8	11.9	43.1	27.9	62.3	30.4	45.7
11	-11.7	33.8	12.5	44.3	28.8	63.8	31.3	46.8
12	-11.1	34.8	13.1	45.4	29.8	65.4	32.3	48.0
13	-10.6	35.8	13.8	46.6	30.7	66.9	33.3	49.3
14	-10.0	36.8	14.4	47.8	31.7	68.5	34.3	50.5
15	-9.4	37.8	15.0	49.0	32.7	70.1	35.3	51.7
16	-8.9	38.8	15.7	50.2	33.7	71.7	36.4	53.0
17	-8.3	39.9	16.4	51.5	34.7	73.4	37.4	54.3
18	-7.8	40.9	17.0	52.7	35.7	75.1	38.5	55.6
19	-7.2	42.0	17.7	54.0	36.8	76.8	39.6	56.9
20	-6.7	43.1	18.4	55.3	37.9	78.5	40.7	58.2
21	-6.1	44.2	19.1	56.6	39.0	80.3	41.8	59.6
22	-5.6	45.3	19.9	58.0	40.1	82.0	42.9	61.0
23	-5.0	46.5	20.6	59.3	41.2	83.8	44.1	62.4
24	-4.4	47.6	21.3	60.7	42.3	85.7	45.2	63.8
25	-3.9	48.8	22.1	62.1	43.5	87.5	46.4	65.2
26	-3.3	50.0	22.9	63.5	44.7	89.4	47.6	66.7
27	-2.8	51.2	23.7	64.9	45.9	91.3	48.8	68.2
28	-2.2	52.4	24.5	66.4	47.1	93.2	50.1	69.7
29	-1.7	53.7	25.3	67.8	48.3	95.2	51.3	71.2
30	-1.1	55.0	26.1	69.3	49.6	97.2	52.6	72.7
31	-0.6	56.2	26.9	70.8	50.8	99.2	53.9	74.3

CONTINUED

TEMPERATURE PRESSURE CHART – at sea level

Pressure (PSIG), Vacuum (in. Of Hg) – Bold Italic Figures
To determine subcooling for 404A, 407C, and 422D, use BUBBLE POINT values (temperatures above 50°F – gray background)
To determine superheat for 404A, 407C, and 422D, use DEW POINT values (temperatures 50°F and below)

TEMP.		REFRIGERANT						
°F	°C	22	134a	404A	407C	410A	422D	507
32	0.0	57.5	27.8	72.4	52.1	101.2	55.2	75.8
33	0.6	58.8	28.6	73.9	53.4	103.3	56.5	77.4
34	1.1	60.2	29.5	75.5	54.8	105.4	57.9	79.0
35	1.7	61.5	30.4	77.1	56.1	107.5	59.3	80.7
36	2.2	62.9	31.3	78.7	57.5	109.7	60.6	82.3
37	2.8	64.3	32.2	80.3	58.9	111.9	62.0	84.0
38	3.3	65.7	33.1	82.0	60.3	114.1	63.5	85.7
39	3.9	67.1	34.1	83.7	61.7	116.3	64.9	87.5
40	4.4	68.6	35.0	85.4	63.2	118.6	66.4	89.2
42	5.6	71.5	37.0	88.8	66.1	123.2	69.4	92.8
44	6.7	74.5	39.0	92.4	69.2	127.9	72.5	96.4
46	7.8	77.6	41.1	96.0	72.3	132.8	75.6	100.2
48	8.9	80.8	43.2	99.8	75.5	137.8	78.9	104.0
50	10.0	84.1	45.4	103.6	78.8	142.9	82.2	108.0
52	11.1	87.4	47.7	109.2	101.7	148.1	96.1	112.0
54	12.2	90.8	50.0	113.3	105.6	153.5	99.8	116.1
56	13.3	94.4	52.4	117.4	109.6	159.0	103.6	120.4
58	14.4	98.0	54.9	121.7	113.7	164.7	107.4	124.7
60	15.6	101.6	57.4	126.0	117.9	170.4	111.4	129.1
62	16.7	105.4	60.0	130.5	122.3	176.3	115.4	133.7
64	17.8	109.3	62.7	135.0	126.7	182.4	119.5	138.3
66	18.9	113.2	65.4	139.7	131.2	188.6	123.8	143.1
68	20.0	117.3	68.2	144.4	135.8	194.9	128.1	147.9
70	21.1	121.4	71.1	149.3	140.5	201.4	132.5	152.9
72	22.2	125.7	74.1	154.3	145.4	208.0	137.1	158.0
74	23.3	130.0	77.1	159.4	150.3	214.8	141.7	163.2
76	24.4	134.5	80.2	164.6	155.4	221.8	146.5	168.5
78	25.6	139.0	83.4	169.9	160.5	228.9	151.3	174.0
80	26.7	143.6	86.7	175.4	165.8	236.1	156.3	179.5
82	27.8	148.4	90.0	181.0	171.2	243.6	161.3	185.2
84	28.9	153.2	93.5	186.7	176.8	251.2	166.5	191.0
86	30.0	158.2	97.0	192.5	182.4	258.9	171.8	197.0
88	31.1	163.2	100.6	198.4	188.2	266.8	177.2	203.0
90	32.2	168.4	104.3	204.5	194.1	274.9	182.7	209.2
92	33.3	173.7	108.1	210.7	200.1	283.2	188.4	215.5
94	34.4	179.1	112.0	217.0	206.3	291.6	194.1	222.0
96	35.6	184.6	115.9	223.4	212.5	300.3	200.0	228.6
98	36.7	190.2	120.0	230.0	219.0	309.1	206.0	235.3
100	37.8	195.9	124.2	236.8	225.5	318.1	212.1	242.2
102	38.9	201.8	128.4	243.6	232.2	327.2	218.4	249.2
104	40.0	207.7	132.7	250.6	239.0	336.6	224.8	256.3
106	41.1	213.8	137.2	257.8	245.9	346.2	231.3	263.7
108	42.2	220.0	141.7	265.1	253.0	355.9	237.9	271.1
110	43.3	226.4	146.4	272.5	260.3	365.9	244.7	278.7
112	44.4	232.8	151.1	280.1	267.6	376.1	251.6	286.5
114	45.6	239.4	156.0	287.9	275.1	386.4	258.6	294.4
116	46.7	246.1	160.9	295.8	282.8	397.0	265.8	302.4
118	47.8	253.0	166.0	303.8	290.6	407.8	273.2	310.7
120	48.9	260.0	171.2	312.1	298.6	418.8	280.6	319.1
125	51.7	278.0	184.6	333.3	319.2	447.4	299.9	340.8
130	54.4	296.9	198.7	355.6	340.7	477.4	320.2	363.6