

**BY ORDER OF THE  
SECRETARY OF THE AIR FORCE**

**AIR FORCE INSTRUCTION 32-1068**

**8 FEBRUARY 2017**

**Civil Engineering**

**HEATING SYSTEMS AND UNFIRED  
PRESSURE VESSELS**



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This instruction implements Air Force Policy Directive (AFPD) 32-10, *Installations and Facilities*, by establishing uniform requirements for installation, operation, maintenance, and inspection of real property installed equipment (RPIE) heating systems and unfired pressure vessels (UPV). It applies only to pressure vessels covered by the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code*. It does not apply to low-pressure boilers below 1 million British thermal units per hour (MBtu/h) output used only for domestic water heating, or pressure vessels containing noncorrosive refrigerants. This publication applies to all Air Force, Air Force Reserve Command (AFRC), and Air National Guard (ANG) units and personnel. It may be supplemented at any level, but all direct supplements must be routed to the Office of Primary Responsibility (OPR) of this Air Force Instruction (AFI) for coordination prior to certification approval. Authorities to waive wing/unit level requirements in this publication are identified with a Tier ("T-0," "T-1," "T-2," "T-3") number following each compliance statement. See AFI 33360, *Publications and Forms Management*, for a description of the authorities associated with the Tier numbers. Submit requests for waivers through the chain of command to the appropriate Tier waiver approval authority, or alternately, to the publication OPR for non-tiered compliance items. Refer recommended changes and questions regarding this publication to the OPR using AF Form 847, *Recommendation for Change of Publication*; route AF Forms 847 from the field through the appropriate functional chain of command. Ensure that all records created as a result of processes prescribed in this publication are maintained in accordance with Air Force Manual (AFMAN) 33-363, *Management of Records*, and disposed of in accordance with the Records Disposition Schedule (RDS) located in the Air Force Records Information Management System (AFRIMS).

## SUMMARY OF CHANGES

This document is substantially revised and must be completely reviewed. This revision adjusts roles to meet the new Civil Engineer structure, updates and clarifies attendance for boiler/hot water generator systems, clarifies all boilers require inspection, and clarifies that boiler installation, inspection, and operational requirements also apply to organizational equipment, mobile boilers, and privately- or contractor-owned boilers. UPV inspection criteria are clarified. Liquefied petroleum tank inspections are moved to a different inspection classification and frequency. Regulatory requirements for boiler tune-ups and energy assessments of Title 40 Code of Federal Regulations Part 63 (40 CFR Part 63), Subpart JJJJJ, February 1, 2013 and Subpart DDDDD, November 20, 2015, were added for Area Source and Major Source boilers to comply with new Boiler Maximum Achievable Control Technology (MACT) rules. Type C operational inspection while under steam pressure or filled with water now includes functional testing in accordance with ASME CSD-1, *Controls and Safety Devices for Automatically Fired Boilers*, or National Fire Protection Association (NFPA) 85, *Boiler and Combustion Systems Hazards Code*, as applicable. This revision supersedes Engineering Technical Letter (ETL) 11-25, *Implementation of Major and Area Source Rules as Applied to Boiler Tune-ups and Energy Assessments for the Boiler MACT Rule*, 8 August 2011.

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**1. Objective.** Air Force heating systems and UPVs must be safe, reliable, and efficient. Build and operate these systems to comply with the ASME *Boiler and Pressure Vessel Code* and conform to federal law.

### 2. Roles and Responsibilities.

2.1. **Headquarters, United States Air Force, Deputy Chief of Staff for Logistics, Engineering and Force Protection, Directorate of Civil Engineer (HQ USAF/A4C)** will.

2.1.1. Develop, maintain, clarify, approve, and publish Air Force Instruction policy.

2.1.2. Develop Management Internal Control Toolset (MICT) Self-Assessment Communicators as part of the oversight strategy.

2.1.3. Directs implementation of applicable public law, safety standards, and Department of Defense (DoD) directives.

2.2. **Air National Guard NGB/A4** will provide supplemental guidance to ANG installations where variations from this instruction is necessary.

2.3. **Air Force Installation and Mission Support Center (AFIMSC)** will: Provide management and guidance to major commands (MAJCOM) and installations.

2.3.1. Oversee and provide solid fuel requisition procedures for overseas bases.

2.3.2. Provide support to MAJCOMs in order to facilitate requests for attendance variances.

2.4. **Air Force Civil Engineer Center (AFCEC)** will:

2.4.1. Provide Air Force Subject Matter Expertise (SME) and technical criteria to Air Force Instructions and guidance for maintaining heating systems and UPVs.

2.4.2. Provide management and technical assistance to base civil engineer organizations.

2.4.3. Provide a centrally funded contract for inspection services at CONUS bases and, if allowed by host nation agreements and standards, OCONUS locations.

2.4.4. Reviews requests for attendance variances.

2.4.5. Approves heating fuel or equipment conversion proposals, including the life-cycle cost analysis.

2.5. **Installation Commander** as the “Responsible Official” under the Clean Air Act (CAA) United States Code Title 42 **Chapter 85**, 40 CFR §70.2, 40 CFR §71.2, 40 CFR §63.7575, 40 CFR §63.11237, and applicable state and local regulations, must certify the truth, accuracy, and completeness of the content of the notifications and reports as discussed in Attachment 3. This duty cannot be delegated. **(T-0)**.

2.6. **Base Civil Engineer (BCE)** will: Ensure boilers, distribution systems, and pressure vessels are constructed, installed, operated, tested, repaired, and maintained in compliance with applicable codes, regulations, federal law, and host nation final governing standards (FGS) at overseas installations.

2.6.1. Develop schedules for inspecting and testing heating systems and UPVs and operate and maintains base heating and distribution systems and UPVs covered by this instruction **(T-2)**.

2.6.2. Determine liquid, solid, and gas utility fuel requirements and ensures safety and adequacy of fuel supplies. **(T-2)**.

2.6.3. Establish and maintains a recurring work program for heating and pressure vessel systems for maximum cost benefit. **(T-2)**.

2.6.4. Establish and maintains a base steam trap maintenance program. **(T-2)**.

2.6.5. Develop and maintains local operating procedures. **(T-2)**.

2.6.6. Maintain operating logs and records of boiler repairs IAW 40 CFR. **(T-0)**.

- 2.6.7. Ensure that inspections are conducted as scheduled and equipment is reliable and safe IAW National Board Inspection Code (NBIC). **(T-0)**. **Note:** AFCEC has a centrally procured contract for boiler and pressure vessel inspections. Reference A2.2.8 for scheduling instructions.
- 2.6.8. Process and post inspection reports and report unsafe boilers or pressure vessels to the base safety office and AFIMSC points of contact (POC). **(T-2)**.
- 2.6.9. Establish a program to measure performance of heating systems in order to make continuous improvements; BCE will review metrics from this program annually. **(T2)**.
- 2.6.10. Assign properly trained experienced personnel. **(T-2)**.
- 2.6.11. Ensure heat plant operating personnel are licensed to meet state and Environmental Protection Agency (EPA) requirements, or host nation FGS at overseas installations. **(T-0)**.
- 2.6.12. Ensure system effluents conform to applicable standards. **(T-1)**.
- 2.6.13. Ensure waste is burned only in approved furnaces. **(T-1)**.
- 2.6.14. Recommend recurring work requirement changes for engineering short- and long-range system replacement planning. **(T-3)**.
- 2.6.15. Ensure approved repairs or alterations are programmed and accomplished. **(T3)**.
- 2.6.16. Ensure all boilers, pressure vessels, and pressure piping systems are constructed, installed, tested, repaired, or replaced to meet ASME or equivalent host nation requirements. **(T-0)**.
- 2.6.17. Ensure all boiler fuel piping and controls meet NFPA or equivalent host nation requirements. **(T-0)**.
- 2.6.18. Develop cost-effective alternatives for system and equipment monitoring, where feasible. **(T-2)**.
- 2.6.19. Analyze and plans operations, maintenance, and repair workloads. **(T-2)**.
- 2.6.20. Ensure efficient management of service contracts and warranty programs for maintenance and repair of heating systems. **(T-2)**.
- 2.6.21. Ensure all construction projects involving heat plants and distribution systems comply with requirements of this instruction and environmental permits and regulations. **(T-0)**.
- 2.6.22. Ensure technical engineering support is provided for planning, design, management, and execution of heating system projects. **(T-2)**.
- 2.6.23. Approves temporary repairs to distribution systems. **(T-2)**.
- 2.6.24. Plan, program, and budget for routine and reoccurring operations, maintenance, and environmental compliance activities (e.g., tune-ups and energy assessments). **(T-1)**.
- 2.6.25. In consultation with the Base Civil Engineer Environmental function's Air Quality Program Manager will:

- 2.6.25.1. Determine if facility is an Area or Major Source for hazardous air pollutants (HAPs). Then, accordingly, ensure records documenting tune-ups, energy assessments, and operational tests are produced and maintained as required by 40 CFR Part 63, Subparts DDDDD (Major Source) or JJJJJ (Area Source). **(T-0)**.
- 2.6.25.2. Prior to any construction or reconstruction of boilers or process heaters, identify and address any appropriate permitting and environmental impact assessment requirements in accordance with AFI 32-7040, *Air Quality Compliance and Resource Management*, and 40 CFR. **(T-0)**.
- 2.6.25.3. Ensure boiler tune-ups and associated reporting are performed as required by 40 CFR Part 63, Subparts DDDDD (Major Source) or JJJJJ (Area Source) as outlined in paragraph 3.5.5.8 and Attachment 3. **(T-0)**.
- 2.6.25.4. Ensure energy assessments and associated reporting are performed in accordance with 40 CFR Part 63, Subparts DDDDD (Major Source) or JJJJJ (Area Source) as outlined in paragraph 3.5.5.8 and Attachment 3. **(T-0)**.
- 2.6.26. Maintains a boiler and unfired pressure vessel inventory using AF mandated IT systems, via Builder and Sustainment Management Systems (SMS) **(T-0)**. At minimum the following information is required:
- 2.6.26.1. Building number and facility category code in which the boiler is installed.
  - 2.6.26.2. Manufacturer and model number.
  - 2.6.26.3. Type (low/medium/high temperature water (LTW/MTW/HTW) or steam) and capacity in 1,000 Btu/hour (MBtu/h) input.
  - 2.6.26.4. Operating temperature and pressure.
  - 2.6.26.5. Fuel type (i.e., natural gas, #2 fuel oil, coal, etc.)
  - 2.6.26.6. Identify boiler as 'primary' or 'backup.'
  - 2.6.26.7. National Board (NB) number.
  - 2.6.26.8. Inspection reports.

### 3. Requirements.

3.1. **Fuel Conversion.** Public law requires Air Force heating systems use the most cost-effective fuel as determined by life-cycle cost analysis. BCE will evaluate fuel suitability, availability, environmental impact, reliability, and maintainability when considering fuel conversion and use life-cycle costing methods, procedures, and information as described in National Institute of Standards and Technology (NIST) Handbook 135, *Life-Cycle Costing Manual for the Federal Energy Management Program*, and escalation factors found in the *NIST Annual Supplement: Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis*. **(T-0)**.

#### 3.2. Solid Fuels.

##### 3.2.1. Requisitions.

3.2.1.1. Request for Coal Purchase. Prepare DD Form 416, *Purchase Request for Coal, Coke, or Briquettes*, and submit to Defense Logistics Agency (DLA), DLA

Energy-AC, 8725 John J. Kingman Road, Room 3830, Fort Belvoir, Virginia 22060-6222, according to dates and instructions specified by DLA Energy-AC. Requisition and acceptance procedures for overseas bases will be provided by AFIMSC. **(T2)**.

3.2.1.2. Placing Orders. The Operations Flight must submit a DD Form 1155, *Order for Supplies or Services*, in accordance with DLA Energy-AC instructions and at least 30 days prior to the desired delivery date. **(T-2)**.

3.2.2. Accepting Deliveries. Before accepting a delivery, central heat plant personnel must inspect each shipment prior to unloading and at the point and time of delivery, according to the DLA Energy-AC contract for the base. Send out samples from the coal shipment for analysis according to the DLA Energy-AC contract for the base.

3.2.2.1. Sampling. Heat plant personnel must take coal samples according to the DLA Energy-AC contract for the base. **(T-0)**. Refer to Military Standard (MIL-STD) 3004D, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products*, Appendix C, and the applicable contract for coal sampling procedures and specific requirements. The boiler plant must maintain a record of the sampling and testing results. **(T-1)**. Inform the Base Civil Engineering Environmental function's Air Quality Program Manager that the sampling and testing results are available.

3.2.2.2. Non-Conforming Coal. The coal sampler will notify the Operations Flight Chief and the Base Civil Engineering Environmental function's Air Quality Program Manager when a coal delivery does not comply with the contract, and recommend rejection to DLA Energy-AC. **(T-2)**. **Note:** The DLA Energy-AC contracting officer is the final authority for rejecting a coal shipment.

3.2.3. Inspecting Coal Stockpiles. Heat plant personnel must inspect coal stockpiles at least twice per week. **(T-3)**. Heat plant personnel must investigate abnormally high temperatures or signs of spontaneous combustion. **(T-3)**. To measure internal temperature use a temperature probe (or other proven method). If internal temperature rises above 160 degrees Fahrenheit (°F), coal may ignite.

3.3. **Liquid Fuels.** This section describes procedures for testing fuel quality, processing liquid fuel requisitions, managing organizational fuel tanks, fuel sampling, and mixing and burning waste fuel with heating fuel.

3.3.1. Liquid Fuels Quality. All fuels to be burned must meet the requirements of Technical Order (T.O.) 42B-1-1, *Quality Control of Fuels and Lubricants*, **Chapter 6**. **(T-1)**.

3.3.2. Requisitions. BCE will submit liquid fuel requirements for each fiscal year to the base fuels management office (FMO). **(T-3)**.

3.3.3. Managing Organizational Fuel Tanks. Tanks owned or operated by the BCE must meet the requirements of AFI 23-204, *Organizational Fuel Tanks*, and AFI 32-7044, *Storage Tank Environmental Compliance*. **(T-1)**.

3.3.4. Sampling and Testing. Fuel sampling is the responsibility of the receiving organization. The BCE will coordinate sampling and testing of fuel received in tanks with the local Fuels Management Team (FMT) to assure fuel quality per T.O. 42B-1-1. **(T-1)**. The boiler plant must maintain a record of the sampling and testing results. **(T-1)**.

Sampling and testing results should be made available to the Base Civil Engineering Environmental Function's Air Quality Program Manager.

3.3.5. Mixing and Burning Waste Fuel and Lubricants with Heating Fuel and Burning Biodiesel. Coordinate requests through the BCE with the Base Civil Engineer Environmental Function to obtain AFCEC/CZO approval before mixing and burning waste fuel and lubricants with heating fuel. Biodiesel fuel and biodiesel blends exceeding B5 (5% biodiesel) will not be burned in boilers. **(T-2)**.

3.4. **Process Steam.** Where possible, supply process steam which wastes condensate (such as steam cleaning) from dedicated boilers.

3.5. **Heating and Distribution Systems and Unfired Pressure Vessels (UPV).** BCEs must ensure design and construction of steam boilers, hot water generators, heating and distribution systems, UPVs, and pressure piping systems comply with the *ASME Boiler and Pressure Vessel Code* or equivalent host nation requirements and this instruction. **(T-0)**. The code requires the design of all steam and hot water heating systems must include equipment to provide industrial water treatment (see AFI 32-1054, *Corrosion Control*). Boilers and UPVs must have a pressure-relieving device as required by the *ASME Boiler and Pressure Vessel Code*, which requires all steam pressure-reducing valve stations on the low-pressure side to have a correctly rated and sized pressure-relief device and compressed air receivers less than 1.5 ft<sup>3</sup> must have the manufacturer's standard pressure-relieving device. BCEs shall ensure all pressure vessels in which moisture can accumulate must have automatic condensate drainage. **(T-1)**.

3.5.1. Operating Boilers and Hot Water Generators. Safe operation of boilers and hot water generators require qualified operating technicians to be on hand to detect and correctly respond to equipment malfunctions or irregularities that could disrupt service, cause a hazard, or damage equipment.

3.5.1.1. Attendance. Table 3.1 shows the minimum frequency for technicians to attend (check and adjust control settings during operation) boilers and hot water generators, based on heating plant capacity (combination of all units used to produce heat that is transmitted through distribution system to a building or group of buildings) and operating pressure and is applicable to all type of fuel sources. Unless host nation agreements or standards require more frequent visits, operating technicians must attend assigned boilers per the minimums shown in Table 3.1 **(T1)**. Variances to Table 3.1 prior to 1 June 2016 must have been approved by MAJCOM and variances after that date must be routed through appropriate AFIMSC channels for approval. **(T-1)**. Requests for variances must include a complete description of the boiler system, control technology, proposed operating procedures, and frequency of attendance. **(T-1)**.

3.5.1.2. High Pressure Steam, Medium and High Temperature Water Plants. Plants that produce high pressure steam (HPS), greater than 15 psig; MTW, 30-160 psig (250–350 °F); and HTW at greater than 160 psig; must have technicians present that are fully qualified for the operation of the particular system and should be licensed to meet environmental regulatory agency requirements. **(T-1)**.

3.5.1.3. Remote Monitoring. Remote monitoring is defined as a condition where boiler controls and safeties are automated and continuously monitored by a system-trained technician from a remote location, with the capability for safe shutdown of all units. The remote location requires the following capabilities: ability to monitor network failure alarms, ability to view water level (steam)/water pressure and temperature (MTW and HTW), stack temperature, feedwater flow (steam)/make-up flow (MTW and HTW), steam flow/circulation flow (MTW and HTW), fuel flow at burner, and video camera installed to view boiler/hot water generator front. Use of proper remote monitoring may be used to support a request for variance to attendance requirements. It is recommended all steam boilers operating at or above 15 psig or hot water generators operating at or above 30 psig which are not required to be constantly attended, be remotely monitored. Per NFPA 85, *Boiler and Combustion Systems Hazards Code*, remote monitoring must not override (prevent) any boiler or hot water generator safety shutdown. **(T-0)**.

**Table 3.1. Minimum Boiler Attendance.**

Heating Medium	Total Boiler Capacity <sup>1</sup>	Operating Pressure and Temperature	Frequency of Attendance <sup>2</sup>	Log Required
Low Temp Water (LTW)	Under 5,000,000 Btu/h	Under 30 psig 250 °F Max	Once per month when operating	No
Low Temp Water (LTW)	5,000,000 Btu/h or greater	Under 30 psig 250 °F Max	Once per 24 hour period during operation <sup>3</sup>	No
Medium Temp Water (MTW)	Under 5,000,000 Btu/h	30–160 psig 250–350 °F	Once per 8-hour shift during operation <sup>3</sup>	No
Medium Temp Water (MTW)	5,000,000 Btu/h to 30,000,000 Btu/h	30–160 psig 250–350 °F	Twice per 8-hour shift during operation <sup>3</sup>	No
Medium Temp Water (MTW)	Over 30,000,000 to 100,000,000 Btu/h	30–160 psig 250–350 °F	Constant attendance by one person per 8-hour shift <sup>4</sup>	No
Medium Temp Water (MTW)	Over 100,000,000 Btu/h	30–160 psig 250–350 °F	Constant attendance by two people per 8-hour shift <sup>4</sup>	No
High Temp Water (HTW)	Under 30,000,000 Btu/h	Over 160 psig Over 350 °F	Twice per 8-hour shift during operation	Yes
High Temp Water (HTW)	30,000,000 Btu/h or greater	Over 160 psig Over 350 °F	Constant attendance by two people per 8-hour shift <sup>4</sup>	Yes
Low Pressure Steam (LPS)	Under 1,000,000 Btu/h	Under 15 psig 212–250 °F	Once every week during operation	No
Low Pressure Steam (LPS)	1,000,000 Btu/h to 5,000,000 Btu/h	Under 15 psig 212–250 °F	Twice per week during operation	No
Low Pressure Steam (LPS)	Over 5,000,000 Btu/h	Under 15 psig 212–250 °F	Once per 24 hour period during operation <sup>3</sup>	Yes
High Pressure Steam (HPS)	Under 5,000,000 Btu/h	Over 15 psig Over 250 °F	Once per 8-hour shift during operation <sup>3</sup>	Yes
High Pressure Steam (HPS)	5,000,000 Btu/h to 30,000,000 Btu/h	Over 15 psig Over 250 °F	Twice per 8-hour shift during operation	Yes
High Pressure Steam (HPS)	Over 30,000,000 Btu/h to 100,000,000 Btu/h	Over 15 psig Over 250 °F	Constant attendance by two people per 8-hour shift <sup>4</sup>	Yes
High Pressure Steam (HPS)	Over 100,000,000 Btu/h	Over 15 psig Over 250 °F	Constant attendance by two people per 8-hour shift <sup>4</sup>	Yes



**Notes:**

1. The sum of the all rated capacities of boilers and hot water generators in the facility, regardless of operating status.
2. For coal-fired plants, additional operating personnel are required for coal and ash handling consistent with installed equipment.
3. Attendance can be accomplished by remote monitoring, with approved variance, and a system-trained technician with the capability for safe shutdown of all units.
4. Attendance can be reduced by one person per 8-hour shift if boiler controls and safeties are automated and continuously monitored, with the minimum items listed in paragraph 3.5.1.2., by a system-trained technician from a remote location with the capability for safe shutdown of all units.

3.5.2. Operating Logs. Heat plant logs give the heat plant foreman and supervisory and management personnel a summary of boiler plant operations and performance and establishes a basis for conformance with environmental air quality permits. For this purpose, use AF Form 1163, *Daily High Temperature Water Plant Operating Log*; AF Form 1165, *Monthly High Temperature Water Plant Operating Log*; AF Form 1458, *Daily Steam Boiler Plant Operating Log*; AF Form 1459, *Water Treatment Operating Log for Steam and Hot Temperature Water Boilers*; or AF Form 1464, *Monthly Steam Boiler Plant Operating Log*. Computer-generated printouts are acceptable if they contain all pertinent information. The operating logs may be used for any boiler plant the operations flight deems appropriate. The heat plant foreman or operations flight maintenance chief must maintain boiler plant performance and operating logs for the following boilers: **(T-1)**.

3.5.2.1. HPS operating over 15 psig and 250 °F.

3.5.2.2. HTW boiler plant operating over 160 psig.

3.5.2.3. Low-pressure steam (LPS) boiler plant with minimum output capacity of 5,000,000 Btu/h.

3.5.3. Maintenance. At dual-fuel plants, fire boilers at least bimonthly with standby fuel to confirm reliability. Overhaul equipment and accomplish other major maintenance during off-peak periods. Annually calibrate boiler instrumentation. Ensure that replacement materials and parts comply with boiler code safety standards. Maintain equipment ASME code stamps and labels in legible condition. The BCE must ensure that scheduled maintenance of boilers, heating equipment, and steam traps is performed. **(T2)**.

3.5.3.1. Pressure Vessel Welding. The ASME *Boiler and Pressure Vessel Code*, Section IX, "Welding and Brazing Qualifications," contains welding procedural specifications and welder qualification requirements. BCE will not allow welding or brazing of pressure components of steam-jacketed cooking equipment or UPV. **(T-0)**. Owing organization must replace failed parts. **(T-0)**.

3.5.3.2. Distribution Systems. Perform maintenance according to the manufacturer's recommendations and appropriate repair codes.

3.5.3.2.1. Existing Systems. Operations Flight will at least annually check the system leaks using thermograph technology or other approved testing methods as recommended by the manufacturer in addition to checking for damage and loss of

insulation. **(T-2)**. Repair damaged lines as necessary to maintain insulating qualities.

3.5.3.2.2. Failed Distribution Lines. Make temporary repairs to failed lines as soon as conditions permit. BCE will program the replacement of failed sections as soon as the extent of failure is known. **(T-2)**.

3.5.3.2.3. Temporary Repairs. Temporary repairs to direct buried systems using piping other than prefabricated conduit systems are permitted. Limit these repairs to 500 feet per repair. BCE will replace these repairs within 18 months with an approved system and materials. **(T-2)**. Repair material must be suitable for use under the pressure and temperature conditions of the distribution system being repaired.

3.5.3.2.4. Cathodic Protection Systems. Where cathodic protection is installed, Operations Flight will inspect, test, and maintain distribution lines in accordance with AFI 32-1054 and Unified Facilities Criteria (UFC) 3-570-06, *Operation and Maintenance: Cathodic Protection Systems*. **(T-2)**.

3.5.4. Replacing or Installing New Distribution Lines. Before replacing failed lines or installing new lines, select a route and then a system type.

3.5.4.1. Route Selection. The system route should be coordinated with the facility master plan. The selected route has considerable impact on system type selection. For example, aboveground systems usually are not acceptable if they create obstructions to traffic or are unsightly, while large numbers of obstructions along the system profile greatly increase the cost of underground systems. Attention should be given to any severe or complex installation conditions that adversely affect the cost of the system. The final route selected should minimize the system life-cycle cost.

3.5.4.2. System Type Selection. BCE will evaluate potential heat distribution system types according to the following order of preference: (1) aboveground; (2) shallow concrete trench; (3) direct buried prefabricated conduit; (4) poured-in-place underground insulation system. **(T-2)**. Select the most cost-effective system based on the results of a life-cycle cost analysis. **(T-1)**. Calculate heat loss for each system under consideration by using standard American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) methods. **(T-2)**. Evaluate life-cycle costs of the alternatives by using the Building Life-Cycle Cost Program (BLCC) available at the Federal Energy Management Program web site. **(T-2)**.

3.5.4.3. System Design and Construction of New or Replacement Distribution Systems. BCE will design and construct new and replacement distribution systems to meet the requirements of UFC 3-430-01FA and applicable Unified Facilities Guide Specifications (UFGS). **(T-1)**. UFCs and UFGS are available at the Whole Building Design Guide ([www.wbdg.org](http://www.wbdg.org)).

3.5.4.4. Installation of Repair Sections. When not otherwise designed, CE will install and test new system components per the UFGS, manufacturer's requirements, or by other approved methods. Complete all tests and correct deficiencies prior to insulating or covering connections, joints, welds, or fittings. **(T-1)**. An authorized factory representative is recommended during installation and testing of systems.

### 3.5.5. Inspections and Testing.

#### 3.5.5.1. Methods and Criteria.

3.5.5.1.1. The United States, Its Territories and Possessions. Boilers and UPVs must be inspected according to NBIC. **(T-0)**.

3.5.5.1.2. Foreign Countries. Boilers and UPVs must be inspected according to host nation agreement or standards if comparable (minimally) to the NBIC; otherwise, follow the NBIC guidelines. **(T-0)**.

3.5.5.1.3. Air National Guard (ANG) Inspection Criteria. ANG will inspect boilers and UPVs according to state, local, and NBIC inspection criteria for inspections at ANG bases. **(T-0)**.

#### 3.5.5.2. Boilers and Fired Pressure Vessels.

3.5.5.2.1. BCE must inspect high pressure steam boilers and HTW generators and expansion tanks in active use with NBIC certified inspectors. **(T-0)**. (See A2.2.9). See Attachment 2 for descriptions of inspection types, frequency of inspection, and scheduling guidelines.

3.5.5.2.1.1. High-pressure steam boilers operate above 15 psig.

3.5.5.2.1.2. HTW generators operate above 160 psig or 350°F.

3.5.5.2.2. Inspect low pressure heating boilers in active use. Inspection and evaluation must be performed by properly qualified personnel, as determined by the BCE or contracted boiler owner/operator. **(T-1)**. These include:

3.5.5.2.2.1. Steam boilers with safety valves set at 15 psig or less.

3.5.5.2.2.2. Hot water boilers with safety valves set at 45 psig or less.

3.5.5.2.2.3. Pressure vessels of less than 33,500 Btu/h specially constructed for laboratory purposes.

3.5.5.3. Steam-Jacketed Cooking Equipment. To comply with NBIC, inspect steam kettles and other steam-jacketed cooking equipment according to the manufacturer's instructions or perform a Type VB inspection (see Attachment 2) with hydrostatic test, excluding internal inspection, once every three years. The hydrostatic test pressure must equal the safety valve set pressure. If steam-jacketed cooking equipment is not coded as RPIE it is organizational equipment, and the provisions in paragraph 3.6 apply.

3.5.5.4. Unfired Pressure Vessels (UPV) Inspection Requirements. The following inspections allow UPVs to comply with NBIC requirements.

3.5.5.4.1. Every three years, Operations Flights must inspect UPVs internally and externally according to the following criteria and as illustrated in Figure 3.1: **(T-0)**.

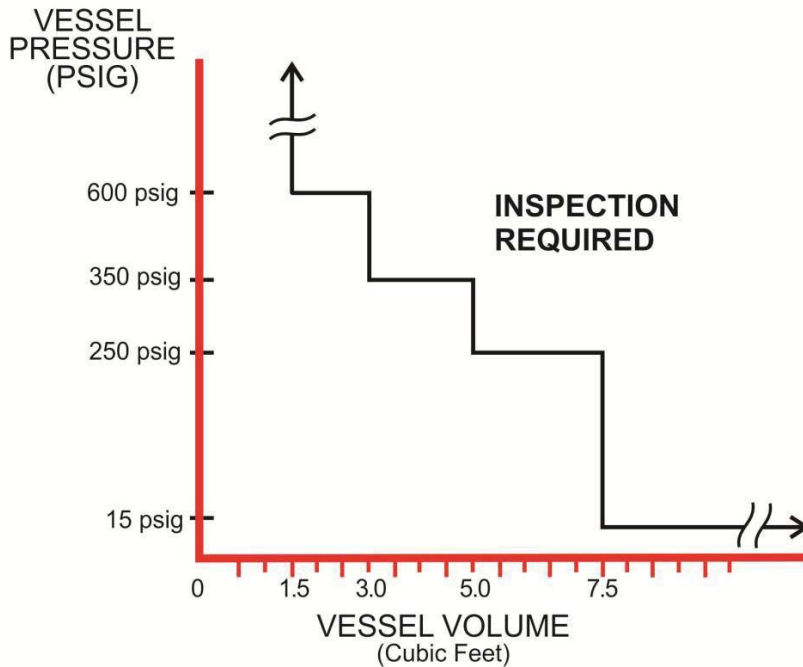
3.5.5.4.1.1. UPVs greater than 1.5 cubic feet in volume and greater than 600 psig design pressure.

3.5.5.4.1.2. UPVs greater than 3 cubic feet in volume and greater than 350 psig design pressure.

3.5.5.4.1.3. UPVs greater than 5 cubic feet in volume and greater than 250 psig design pressure.

3.5.5.4.1.4. UPVs greater than 7.5 cubic feet in volume and greater than 15 psig design pressure.

**Figure 3.1. Unfired Pressure Vessel (UPV) Inspection Requirements.**



3.5.5.4.2. A NBIC Certified inspector will perform a hydrostatic test to 1.5 times working pressure every three years on vessels operating above 200 psig that cannot be inspected internally and externally. **(T-0)**.

3.5.5.4.3. A NBIC Certified inspector will inspect unfired steam pressure vessels which operate at pressures above 15 psig every three years or more frequently as determined by procedures in the NBIC. **(T-0)**. Perform a Type VB inspection with a hydrostatic test to 1.5 times working pressure every three years on vessels operating above 200 psig that cannot be inspected internally and externally. **(T-0)**. Where applicable, pressure vessels without access for internal inspections must be inspected by non-destructive testing (NDT) procedures. **(T-0)**.

3.5.5.4.4. The following categories of UPVs are excluded from the specific inspection requirements:

3.5.5.4.4.1. UPVs with an inside diameter, width, height, or cross-section diagonal not exceeding 6 inches but with no limitation on length or pressure.

3.5.5.4.4.2. Pressure vessels for human occupancy.

3.5.5.4.4.3. Fired process tubular heaters.

3.5.5.4.4.4. UPVs with an internal or external operating pressure not exceeding 15 psig but with no limitation on size.

3.5.5.4.4.5. Hot water storage tanks heated by steam or other means when the following limitations are not exceeded: a nominal water-containing capacity of 120 gallons; a water temperature of 210 °F; and heat input of 200,000 Btu/hr.

3.5.5.4.4.6. UPVs for containing water under pressure, including vessels containing air, the compression of which serves only as a cushion, when the following limitations are not exceeded: a design pressure of 300 psig and a design temperature of 210 °F.

3.5.5.4.4.7. Any structure whose primary function is transporting fluids from one location to another within a system of which it is an integral part (i.e., piping systems).

3.5.5.5. Reporting Inspections. Inspectors will report all boiler and pressure vessel inspection using AF Form 1222, *Boiler or Pressure Vessel Inspection Report*. Inspectors will promptly notify the BCE, base safety office, and AFIMSC Detachment when a boiler or pressure vessel is unsafe to operate. **(T-2)**. The AFIMSC Detachment may issue separate reporting instructions. BCE must post one copy of the inspection report (under a transparent protective cover) in a conspicuous location near the boiler or pressure vessel, send one copy to the operations flight; place one copy in the file. **(T-1)**.

3.5.5.6. Post-Inspection Repairs. Before leaving the base the inspector will report any serious defects to the operations flight. Take corrective actions requested by the inspector or listed on the inspection reports. If a boiler or pressure vessel is unsafe to operate, proper repairs must be made before placing it on-line. **(T-0)**. All repairs to pressure components of boilers or UPVs and safety pressure-relief devices must be performed by an organization holding the appropriate NBIC code stamp and in accordance with ASME Boiler and Pressure Vessel Code. **(T-0)**.

3.5.5.7. Reporting Repairs. After inspecting the repairs (reference A2.2.4), BCE will post one copy of the inspection report describing repair actions (under a transparent protective cover with the original inspection report); send one copy to the operations flight; place one copy in the file. **(T-1)**.

3.5.5.8. Boiler Tune-ups and Energy Assessments.

3.5.5.8.1. Environmental Regulatory Requirements. Tune-ups are routinely required for all operational boilers depending on the boiler's input capacity, fuel type, and the facility's HAP classification (e.g., Major or Area Source). Many existing boilers are also required to undergo a one-time energy assessment. Energy assessments identify energy conservation measures to reduce heating system energy demand. The Major Source and Area Source tune-up and energy assessment requirements are listed in 40 CFR Part 63, Subpart JJJJJ (Area Source) and Subpart DDDDD (Major Source) and summarized in Attachment 3.

The minimum tune-up requirement is trimming (adjusting) the combustion air within the limits prescribed by the manufacturer and per the requirements as outlined in Tables A3.1 through A3.4. If automatic trim controls are not installed, a portable flue gas analyzer may be used. Follow the sampling procedures prescribed in ASME Code PTC 19.10-1981, *Flue and Exhaust Gas Analyses*, Appendix 4. Include all other manufacturer-identified maintenance actions that are due or recommended to be performed on an annual basis. Per 40 CFR, documentation of energy assessment and tune-ups must be maintained at base-level civil engineer unit. **(T-0)**. For further guidance, refer to Attachment 3, “Implementation of Major and Area Source Rules as Applied to Boiler Tune-ups and Energy Assessments for the Boiler National Emission Standards for Hazardous Air Pollutants (NESHAP) Rules.”

3.5.5.8.2. Non-Environmental Requirements. All other boilers exempt from the environmental requirements above, regardless of size or fuel type, must be trimmed (adjusting combustion air within the limits prescribed by the manufacturer and per the requirements as outlined in Tables A4.1 through A4.4.) and receive all manufacturer-identified recommended maintenance actions annually. **(T-1)**. Follow the sampling procedures prescribed in ASME Code PTC 19.10-1981, *Flue and Exhaust Gas Analyses*, Appendix 4 with a calibrated portable flue gas analyzer to determine combustion efficiency. No combustion analysis is required if an oxygen trim system is installed on a boiler

3.5.5.9. Combustion Efficiency. All boilers must be operated within the manufacturer’s specified range for excess combustion air (or excess O<sub>2</sub>). **(T-1)**. This ensures that boilers operate within a narrow range of optimal combustion efficiencies. Attachment 4, “Tuning Boilers for Maximum Efficiency,” lists combustion efficiency tables that can be used to identify the expected combustion efficiencies for natural gas and oil-fired boilers operating within various operating parameters.

3.5.6. Boiler Replacement. Boilers should be replaced at the end of their useful life. This condition is met when it is not possible to restore the boiler to a safe, operating condition and/or when it is no longer economical to operate versus the life cycle cost of a new boiler. To determine whether or not a boiler has met or exceeded its useful economic life, a life cycle cost analysis (LCCA) per the methodology outlined in 10 CFR 436 is required.

**3.6. Organizational Equipment, Mobile Boiler, and Privately or Contractor-Owned** located on Air Force installations must be operated safely and comply with the provisions of paragraph 3.5 through paragraph 3.5.5.9. to comply with 40 CFR. The unit owning organization or contract quality assurance evaluator (QAE) must monitor these boilers and UPVs to ensure the operator/owner will:

3.6.1. Comply with basic safety practices similar to those required for government boilers and UPVs. **(T-1)**.

3.6.2. Arrange for periodic safety inspections. **(T-1)**.

3.6.3. Schedule an authorized inspection agency to perform inspections at the same intervals required for government boilers and UPVs. **(T-1)**.

3.6.4. Post inspection reports as specified for government-operated boilers and UPVs. **(T1). Note:** Per NBIC, the equipment owner must: (1) Make repairs that the inspector recommends; (2) pay for all inspections and repairs; and (3) not operate equipment before repairing it if the inspector declares it unsafe. **(T-0).** Repair equipment according to the NBIC or host country code, as applicable. **(T-0).**

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## Attachment 1

## GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION

*References*

- 42 USC §7412 (Clean Air Act §112), Hazardous air pollutants, <http://www.gpo.gov/fdsys/pkg/USCODE-2011-title42/pdf/USCODE-2011-title42-chap85-subchapI-partA-sec7412.pdf>
- 10 CFR Part 436, *Federal Energy Management and Planning Programs*, [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title10/10cfr436\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title10/10cfr436_main_02.tpl)
- 40 CFR Part 60, *Standards of Performance for New Stationary Sources*, [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr60\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr60_main_02.tpl)
- 40 CFR Part 61, *National Emission Standards for Hazardous Air Pollutants*, [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr61\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr61_main_02.tpl)
- 40 CFR Part 63, *National Emission Standards for Hazardous Air Pollutants for Source Categories*, [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr63\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr63_main_02.tpl)
- 40 CFR Part 63, Subpart DDDDD, *National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters*, <http://www.gpo.gov/fdsys/pkg/CFR-2013-title40-vol14/pdf/CFR-2013-title40-vol14-part63-subpartDDDDD.pdf>
- 40 CFR 63, Subpart EEE, *National Emission Standards for Hazardous Air Pollutants from Hazardous Waste Combustors*, <https://www.gpo.gov/fdsys/pkg/CFR-2012-title40-vol12/xml/CFR-2012-title40-vol12-part63-subpartEEE.xml>
- 40 CFR Part 63, Subpart JJJJJ, *National Emission Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers Area Sources*, <http://www.gpo.gov/fdsys/pkg/CFR-2013-title40-vol15/pdf/CFR-2013-title40-vol15-part63-subpartJJJJJ.pdf>
- 40 CFR 63, Subpart UUUUU, *National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-Fired Electric Utility Steam Generating Units*, <http://www.ecfr.gov/cgi-bin/text-idx?node=40:15.0.1.1.1.8&rgn=div6>
- 40 CFR Part 65, *Consolidated Federal Air Rule*, [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr65\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr65_main_02.tpl)
- 40 CFR Part 70.2, *State Operating Permit Programs; Definitions*, [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr70\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr70_main_02.tpl)
- 40 CFR Part 71.2, *Federal Operating Permit Programs; Definitions*, [http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr71\\_main\\_02.tpl](http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr71_main_02.tpl)
- 80 FR 2871, *National Emission Standards for Hazardous Air Pollutants for Area Sources: Industrial, Commercial, and Institutional Boilers*, January 21, 2015 (proposed rule)



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AFPD 32-10, *Installations and Facilities*, 4 March 2010

AFI 23-204, *Organizational Fuel Tanks*, 24 July 2012

AFI 32-1054, *Corrosion Control*, 7 November 2014

AFI 32-7040, *Air Quality Compliance and Resource Management*, 4 November 2014

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AFI 33-364, *Records Disposition – Procedures and Responsibilities*, 22 December 2006

AFMAN 33-363, *Management of Records*, 1 March 2008

*Air Force Guide for National Emission Standards for Hazardous Air Pollutants for Major Source: Industrial, Commercial, and Institutional Boilers and Process Heaters; 40 CFR Part 63, Subpart DDDDD*

*Air Force Guide for National Emission Standards for Hazardous Air Pollutants for Area Source: Industrial, Commercial, and Institutional Boilers; 40 CFR Part 63, Subpart JJJJJJ.*

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UFC 3-570-06, *Operation and Maintenance: Cathodic Protection Systems*, 31 January 2003

ASME Boiler and Pressure Vessel Code, 2010

ASME Code PTC 19.10-1981, *Flue and Exhaust Gas Analyses*, 1 January 1981

ASME CSD-1, *Controls and Safety Devices for Automatically Fired Boilers*, 2015

ISO 50001:2011, *Energy Management Systems – Requirements with Guidance for Use*

*National Board Inspection Code (NBIC)*, 2013

NFPA 85, *Boiler and Combustion Systems Hazards Code*, 2015

NIST Annual Supplement: *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis*, 2011

NIST Handbook 135, *Life-Cycle Costing Manual for the Federal Energy Management Program*, February 1996

### ***Prescribed Forms***

AF Form 1163, *Daily High Temperature Water Plant Operating Log*

AF Form 1165, *Monthly High Temperature Water Plant Operating Log*

AF Form 1222, *Boiler or Pressure Vessel Inspection Report*

AF Form 1458, *Daily Steam Boiler Plant Operating Log*

AF Form 1459, *Water Treatment Operating Log for Steam and High Temperature Water Boilers*  
AF Form 1464, *Monthly Steam Boiler Plant Operating Log*

### ***Adopted Forms***

AF Form 847, *Recommendation for Change of Publication*  
DD Form 416, *Purchase Request for Coal, Coke, or Briquettes*  
DD Form 1155, *Order for Supplies or Services*

### ***EPA Forms***

Initial Notification of Applicability (Area Sources),  
[http://www.epa.gov/ttn/atw/boiler/imptools/area\\_initial\\_notification.doc](http://www.epa.gov/ttn/atw/boiler/imptools/area_initial_notification.doc)

Initial Notification of Applicability (Major Sources),  
<http://www.epa.gov/ttn/atw/boiler/imptools/majornotificationofapplicability.docx>

Tune-up Information,  
[http://www.epa.gov/ttn/atw/boiler/imptools/area\\_tuneup\\_info\\_only.docx](http://www.epa.gov/ttn/atw/boiler/imptools/area_tuneup_info_only.docx)

### ***Abbreviations and Acronyms***

°F—degrees Fahrenheit

ΔT—change in temperature/ambient

AF/A4CE—Directorate of Civil Engineer, Energy and Environment Division

AF/A4CS—Directorate of Civil Engineers, Sustainment Division

AFCEC/CO—Air Force Civil Engineer Center, Operations Directorate

AFCEC/CZO—Air Force Civil Engineer Center, Environmental Directorate, Operations Division

AFCEC/CZTQ—Air Force Civil Engineer Center, Compliance Technical Support

AFCEC—Air Force Civil Engineer Center

AFI—Air Force Instruction

AFIMSC—Air Force Installation and Mission Support Center

AFMAN—Air Force Manual

AFPD—Air Force Policy Directive

AFRC—Air Force Reserve Command

AFRIMS—Air Force Records Information Management System

ANG—Air National Guard

APIMS—Air Program Information Management System

ASHRAE—American Society of Heating, Refrigeration, and Air-conditioning Engineers

ASME—American Society of Mechanical Engineers

**BCE**—Base Civil Engineer  
**BLCC**—Building Life Cycle Cost  
**Btu**—British thermal unit  
**Btu/h**—British thermal units per hour  
**CAA**—Clean Air Act  
**CDX**—central data exchange  
**CEDRI**—Compliance and Emissions Data Reporting Interface  
**CFR**—Code of Federal Regulations  
**CONUS**—continental United States  
**COR**—Contracting Officer’s Representative  
**DD**—Department of Defense (form)  
**DLA**—Defense Logistics Agency  
**DoD**—Department of Defense  
**EGU**—electrical (utility steam) generating unit  
**EPA**—Environmental Protection Agency  
**ETL**—Engineering Technical Letter  
**FAX**—facsimile (telecopying)  
**FGS**—Final Governing Standards  
**FMO**—Fuels Management Office  
**FMT**—Fuels Management Team  
**FR**—Federal Register  
**HAP**—hazardous air pollutant  
**HHV**—high heating value  
**HPS**—high-pressure steam  
**HTW**—high-temperature water  
**HVAC**—heating, ventilation, air conditioning  
**IAW**—in accordance with  
**ISO**—International Organization for Standardization  
**LCCA**—life cycle cost analysis  
**LPS**—low-pressure steam  
**LTW**—low-temperature water  
**MACT**—Maximum Achievable Control Technology

**MICT**—Management Internal Control Toolset  
**MAJCOM**—major command  
**MBtu/h**—thousand British thermal units per hour  
**MIL-STD**—military standard  
**MMBtu/hr**—million British thermal units per hour (Roman numeral M = 1000)  
**MTW**—medium-temperature water  
**NB**—National Board  
**NBIC**—National Board Inspection Code  
**NDT**—non-destructive testing  
**NESHAP**—National Emission Standards for Hazardous Air Pollutants  
**NFPA**—National Fire Protection Association  
**NIST**—National Institute of Standards and Technology  
**NOC**—Notification of Compliance (Status Report)  
**OCONUS**—outside continental United States  
**O&M**—operation and maintenance  
**OPR**—Office of Primary Responsibility  
**POC**—point of contact  
**psia**—pounds per square inch absolute  
**psig**—pounds per square inch gauge  
**QAE**—quality assurance evaluator  
**RDS**—Records Disposition Schedule  
**RPIE**—real property installed equipment  
**TBtu**—trillion British thermal units  
**T.O**—Technical Order  
**UFC**—Unified Facilities Criteria  
**UFGS**—Unified Facilities Guide Specification  
**UPV**—unfired pressure vessel  
**USC**—United States Code

### *Terms*

**Affected Boiler (or Affected Source)**—An affected boiler (and process heater for a Major Source) is any non-residential or non-exempt boiler (refer to A3.7. for list of exemptions). For an Area Source, affected boilers include boilers which combust coal, biomass, or oil. For a Major Source, an affected boiler or process heater combusts gas, oil, coal, or biomass.

**Area Source**—Any contiguous area under common control (such as an Air Force installation) that is not a Major Source (i.e., that emits, or has the potential to emit, less than 10 tons per year of any single HAP and less than 25 tons per year of any combination of HAPs).

**Biomass**—Any organically-based solid fuel that is not solid waste. This includes, but is not limited to, wood residue and wood products (e.g., trees, tree stumps, tree limbs, saw dust, chips, and shavings), animal manure, vegetative agricultural and silvicultural materials (e.g., logging residues, nut and grain hulls, chaff, corn stalks).

**Blast furnace gas fuel-fired boiler or process heater**—An industrial/commercial/institutional boiler or process heater that receives 90 percent or more of its total annual gas volume from blast furnace gas.

**Boiler**—An enclosed device using controlled flame combustion and having the primary purpose of recovering thermal energy in the form of steam or hot water.

**Boiler System**—The boiler and associated components, such as the feed water system, the combustion air system, the fuel system (including burners), blowdown systems, combustion control system, and energy consuming systems.

**Electric Boiler**—A boiler in which electric heating serves as the source of heat. Electric boilers that burn gaseous or liquid fuel during periods of electrical power curtailment or failure are included in this definition.

**Energy Assessment**—An energy assessment is an evaluation of energy use to identify the most cost-effective, energy-saving opportunities.

**Energy Use System**—Systems located on-site that use energy (steam, hot water, or electricity) provided by an affected boiler. Includes, but is not limited to, process heating; compressed air systems; machine drive (motors, pumps, fans); process cooling; facility heating, ventilation, and air-conditioning (HVAC) systems; hot water systems; building envelope; and lighting.

**Existing Boiler**—Boilers (and process heaters for a Major Source) constructed or reconstructed on or before 4 June 2010.

**Gaseous Fuel (Gas 1 and Gas 2)**—Includes, but is not limited to, natural gas, propane, process gas, landfill gas, coal derived gas, refinery gas, and biogas.

**Gas-fired Boiler**—Includes any boiler that burns gaseous fuels not combined with any solid fuels and burns liquid fuel only during periods of gas curtailment, gas supply interruption, startups, or periodic testing on liquid fuel. Periodic testing of liquid fuel must not exceed a combined total of 48 hours during any calendar year.

**Hazardous Air Pollutant (HAP)**—HAPs are air pollutants which are known or probable human carcinogens and/or linked to health conditions affecting the lungs, skin, and central nervous system, particularly for people in vulnerable groups such as children and the elderly. Specific HAPs are defined in United States Code Title 42, [Chapter 85](#), Subchapter I, Part A, Section 7412, Hazardous Air Pollutants (42 USC §7412).

**Heavy liquid**—Includes residual oil and any other liquid fuel not classified as a light liquid (residual oils such as #4, #5 & #6 oil).

**High Pressure Steam**—high pressure steam operates at system pressures greater than 15 psig.

**High Temperature Water**—high temperature water operates at system pressures greater than 160 psig.

**Hot Water Heater**—A closed vessel with a capacity of no more than 120 U.S. gallons in which water is heated by combustion of fuel and hot water is withdrawn for use external to the vessel. Hot water boilers (i.e., boilers not generating steam) with a heat input capacity of less than 1.6 million Btu per hour are included in this definition (**Note:** The 120 gallon capacity threshold does not apply to hot water boilers.) Hot water heater also means a tankless unit that provides on-demand hot water.

**Light Liquid**—Includes distillate oil, biodiesel, or vegetable oil. Distillate oil refers to fuel oils that contain 0.05 weight percent nitrogen or less and comply with the specifications for fuel oil numbers 1 and 2 (distillate oil such as #1, #2 oil, biodiesel, vegetable oils).

**Limited-use Boiler/Process Heater**—Any boiler (and process heater for a Major Source) that burns any amount of solid, liquid, or gaseous fuels and has a federally enforceable average annual capacity factor of no more than 10 percent. The annual capacity factor is the ratio between the actual heat input to a boiler or process heater from the fuels burned during a calendar year and the potential heat input to the boiler or process heater had it been operated for 8,760 hours during a year at the maximum steady state design heat input capacity.

**Low Pressure Boiler**—a boiler in which steam or vapor is generated at a pressure less than or equal to 15 psig.

**Low Temperature Water**—low temperature water operates system pressures below 30 psig and temperatures below 250 °F.

**Major Source**—Any contiguous area under common control (such as an Air Force installation) that emits or has the potential to emit, considering controls, in the aggregate, 10 tons per year or more of any single HAP or 25 tons per year or more of any combination of HAPs, unless the EPA administrator establishes a lesser quantity, or, in the case of radionuclides, different criteria from those specified in this paragraph.

**Medium Temperature Water**—medium temperature water operates system pressures between 30 and 60 psig and temperatures in excess of 250 °F.

**New Boiler/Process Heater**—A boiler (and process heater for a Major Source) is new if construction or reconstruction of the boiler or process heater began after 4 June 2010 and the boiler or process heater meets the applicability criteria at the time construction commenced.

**Oxygen Trim System**—A system of monitors that is used to maintain excess air at the desired level in a combustion device. A typical system consists of a flue gas oxygen and/or carbon monoxide monitor that automatically provides a feedback signal to the combustion air controller.

**Period of gas curtailment or supply interruption**—A period of time during which the supply of gaseous fuel to an affected boiler is restricted or halted for reasons beyond the control of the facility. The act of entering into a contractual agreement with a supplier of natural gas established for curtailment purposes does not constitute a reason that is under the control of a facility for the purposes of this definition. An increase in the cost or unit price of natural gas due to normal market fluctuations not during periods of supplier delivery restriction does not constitute a period of natural gas curtailment or supply interruption. On-site gaseous fuel system

emergencies or equipment failures qualify as periods of supply interruption when the emergency or failure is beyond the control of the facility.

**Process Heater**—An enclosed device using a controlled flame with a primary purpose of transferring heat indirectly to a process material (liquid, gas, or solid) or to a heat transfer material (e.g., glycol or a mixture of glycol and water) for use in a process unit, instead of generating steam.

**Reconstructed Boiler/Process Heater**—The boiler (and process heater for a Major Source) is a reconstructed source if reconstruction of the boiler or process heater commenced after 4 June 2010, and met the applicability criteria at the time reconstruction commenced. Reconstruction is the replacement of components such that the total, fixed capital cost of the replacement is greater than 50% or more than the fixed capital cost of constructing a comparable, new unit.

**Residential Boiler**—A boiler used to provide heat and/or hot water and/or as part of a residential combined heat and power system. This definition includes a boiler located at an institutional facility (e.g., military base) or commercial/industrial facility if the boiler is used primarily to provide heat and/or hot water for: (1) a dwelling containing four or fewer families; or (2) a single unit residence dwelling that has since been converted or subdivided into condominiums or apartments.

**Responsible Official**—The Installation/Center Commander as defined by 40 CFR 70.2 and AFI 32-7040, *Air Quality Compliance and Resource Management*; this individual must sign Initial Notice of Compliance Status reports.

**Seasonal Boiler**—A boiler that undergoes a shutdown for a period of at least seven (7) consecutive months (or 210 consecutive days) each twelve-month period due to seasonal conditions, except for periodic testing. Periodic testing must not exceed a combined total of fifteen (15) days during the seven-month shutdown. This definition applies only to boilers that would otherwise be included in the biomass subcategory or the oil subcategory under the Area Source rule.

**Temporary Boiler or Process Heater**—Include any gaseous or liquid fuel boiler (and process heater for a Major Source) that is designed to, and is capable of, being carried or moved from one location to another (for example by wheels, skids, carrying handles, dollies, trailers, or platforms). A boiler or process heater is NOT a temporary if any one of the following conditions exists:

- (1) The equipment is attached to a foundation.
- (2) The boiler or a replacement remains at a location within the facility and performs the same or similar function for more than 12 consecutive months, unless the appropriate regulatory authority grants an extension. Any temporary boiler that replaces a temporary boiler at a location and performs the same or similar function will be included in calculating the consecutive time period.
- (3) The equipment is located at a seasonal facility and operates during the full annual operating period of the seasonal facility, remains at the facility for at least 2 years, and operates at that facility for at least 3 months each year.
- (4) The equipment is moved from one location to another in an attempt to circumvent the residence time requirements of this definition.

**Tune-up**—Adjustments made to a boiler (and process heater for a Major Source) in accordance with the procedures outlined in 40 CFR 63.11223 (for Area Sources) or 40 CFR 63.7540 (for Major Sources).



## Attachment 2

### INSPECTION REQUIREMENTS

#### A2.1. Types of Inspections.

##### A2.1.1. Boilers:

A2.1.1.1. **Type BA:** Internal and external inspection.

A2.1.1.2. **Type BB:** Internal and external inspection followed or preceded by external inspection while boiler is under a hydrostatic test.

A2.1.1.3. **Type BC:** Operational inspection while under steam pressure or filled with water. This inspection also includes verifying that safety devices perform as intended in accordance with ASME CSD-1 or NFPA 85, as applicable.

A2.1.1.4. **Type BD:** External inspection while under hydrostatic test.

A2.1.1.5. **Type BE:** Internal and external inspection of expansion tanks with HTW boilers.

##### A2.1.2. UPVs:

A2.1.2.1. **Type VA:** Internal and external inspection.

A2.1.2.2. **Type VB:** Internal and external inspection followed or preceded by external inspection while pressure vessel is under hydrostatic test.

A2.1.2.3. **Type VC:** External inspection while under operating conditions and pressure.

A2.1.2.4. **Type VD:** External inspection while under hydrostatic test.

A2.1.2.5. **Type VE:** Internal and external inspection with an ultrasonic thickness test of the pressure shell.

#### A2.2. Requirements per NBIC.

##### A2.2.1. HPS Boilers:

A2.2.1.1. Perform a Type BA inspection, including an internal and external inspection, annually. **(T-0)**.

A2.2.1.2. Perform a Type BB inspection, which includes a hydrostatic test, every three years. **(T-0)**. This replaces the Type BA inspection for that year.

A2.2.1.3. Accomplish a secondary inspection (Type BC) annually, approximately six months after the Type BA or BB. **(T-0)**.

##### A2.2.2. HTW Boilers:

A2.2.2.1. Perform an external (Type BC) inspection once a year. **(T-0)**.

A2.2.2.2. Perform an internal inspection (Type BA) after the first and second year of operation. **(T-0)**.

A2.2.2.3. Perform a Type VE inspection on each expansion tank every two years. Perform a Type VC inspection during alternating years. **(T-0)**.

**A2.2.3. Frequency of HTW Boiler Internal Inspections After Two Years.** After operating and inspecting the boiler for two years, extend the frequency of internal inspection to three years if: **(T-0)**.

A2.2.3.1. No adverse conditions such as scale or corrosion are present.

A2.2.3.2. The amount of makeup water is negligible.

A2.2.3.3. Effective chemical treatment is under strict control.

**A2.2.4. Questionable Steam and HTW Boilers.** Perform a Type BB inspection when: (1) a boiler has been reinstalled; or (2) a boiler had major repairs (as defined in the NBIC). Inspect before returning the boiler to normal operation. Perform a Type BA inspection six months after resuming operation. Ensure an NBIC inspector performs a preliminary Type BA or Type BB inspection before initiating a major repair. **(T-0)**.

**A2.2.5. Low/Medium Temperature Water and LPS Heating Boilers.** Perform a Type BC inspection on: (1) hot water (LTW/MTW) heating boilers annually that operate at or below 250 °F and at or below 160 psig; or (2) low-pressure steam boilers (below 15 psig) biannually. Only boilers less than 1 MBtu/h output that produce domestic hot water are exempt from this inspection requirement. Inspections do not require a certified inspector and must be accomplished by experienced, qualified base personnel, as determined by the BCE. **(T1)**.

**A2.2.6. Compressed Air Receivers and Other UPVs.** Perform a Type VE inspection every three years, except for liquefied petroleum (propane) tanks, which require a Type VC inspection every five years. **(T-0)**. When questionable conditions or inspection indicates that a safety problem exists:

A2.2.6.1. Conduct hydrostatic tests.

A2.2.6.2. Notify the AFIMSC Detachment by telephone, followed by e-mail detailing the pressure vessel safety problem and provide a copy of the UPV inspection.

A2.2.6.3. Perform repairs as required.

A2.2.6.4. Perform a Type VE inspection annually until all problems are corrected.

A2.2.6.5. After the inspection indicates that problems are corrected, perform an inspection every three years or five years, as required. **Note:** For pressure vessels that operate over 200 psig and cannot be inspected internally and externally, perform hydrostatic test to 1.5 times working pressure every three years.

**A2.2.7. New Boilers.** Perform a Type BB inspection on all new steam or HTW boilers before operation. **(T-0)**.

**A2.2.8. Scheduling and Obtaining Inspection Services.**

A2.2.8.1. **Continental United States (CONUS) Bases.** AFCEC ensures a centrally funded contract for inspection services is in place. Boilers and pressure vessels are scheduled for the required inspections by the bases every year. **(T-1)**.

A2.2.8.1.1. **Scheduled Inspections.** The BCE schedules inspections according to one of two methods: (1) submits annual inspection requirements according to AFCEC instructions; (2) confirms computer-generated schedules according to AFCEC instructions. **(T-1).**

A2.2.8.1.2. **Unscheduled Inspections.** If a boiler or pressure vessel requires an inspection and is not on the annual schedule, the BCE or a designated representative must request approval for inspection. **(T-2).** Submit the request according to AFCEC instructions when utilizing the central Air Force contract. Provide the AFCEC contracting officer's representative (COR) with a request for unscheduled boiler inspections, including the following information: a point of contact and alternate; commercial phone numbers, including area code; approximate date of inspection; and location of the vessel to be inspected (e.g., building number) by telephone, e-mail or FAX before scheduling the inspections. The contractor must receive approval from the AFCEC COR prior to performing inspections. **(T-1).** Submit required boiler/UPV inspection requirements to NIPR: [afcec.rbc@us.af.mil](mailto:afcec.rbc@us.af.mil) or ask questions through the AFCEC Reach Back Center 888-232-3721/850-283-6995/DSN 312-523-6995.

**A2.2.8.1.3. Special Inspections (CONUS Bases).**

A2.2.8.1.3.1. Perform a special inspection (Type BA or BB) before starting repairs to pressure components. Perform an unscheduled Type BB inspection when repairs to pressure components are complete. Arrange these special inspections through the AFCEC Contracting Officer's Representative (COR). Perform a special inspection after a boiler failure with potential damage or explosion to determine the extent of damage or necessary repairs. Depending upon the boiler condition, a loss analysis or useful life study may need to be conducted. Bases must fund or program for special studies or inspections. Depending on availability of funds, AFCEC may support special tests. **(T-1).**

A2.2.8.1.3.2. If the company under contract cannot make a special or emergency inspection, the BCE may hire an authorized inspection agency. An installation employee must not make these special inspections. **(T-1).**

**A2.2.8.2. Bases Outside the Continental United States (OCONUS).** AFIMSC Detachments serving bases in foreign countries must ensure a boiler inspection program exists to comply with FGS or Host Nation Agreements. **(T-0).** Some host countries have their own boiler inspection program and may require the BCE to use their services. The BCE may request contracted services through their AFIMSC Detachment, using the process discussed in paragraphs A2.2.8.1.1 and A2.2.8.1.2.

**A2.2.8.3. Special Inspections (Bases in Foreign Countries).** AFIMSC Detachments serving these bases must have qualified and competent boiler inspectors perform special inspections. **(T-1).** (Base-level personnel must not supervise these inspectors.) The inspection agency must ensure a completed and signed report for each inspection is given to the Government representative and one copy is sent to the AFIMSC Detachment. **(T1).**

A2.2.9. **Inspector Qualifications.** The NBIC establishes basic qualifications for boiler inspectors in the United States, its territories, and possessions. Inspectors must hold a current National Board Commission. **(T-0).** AFIMSC Detachments must use the NBIC standards for bases in foreign countries if the host country does not have NBIC-equivalent standards. **(T0).**

A2.2.10. **Hydrostatic Testing of Boilers.**

A2.2.10.1. **Establishing Test Conditions.** During hydrostatic tests to determine tightness under Type BB or BD inspections: **(T-0).**

A2.2.10.1.1. Remove safety valves before testing or hold down each disc with a test clamp or plug device designed for this purpose.

A2.2.10.1.2. Ensure water temperature is not less than ambient and between 70 °F and 120 °F.

A2.2.10.1.3. Ensure test pressure is equal to boiler working pressure but not greater than the set pressure of the safety device with the lowest setting. **Note:** For tests under a Type BB inspection, externally inspect the boiler during the safety test at the pressure described above. Set test pressure for inspections of new boilers and existing boilers before and after repairs at 1.5 times the maximum allowable working pressure.

A2.2.10.2. **When to Hydrostatically Test High-Pressure Boilers.** Subject high-pressure boilers to hydrostatic tests only under specific conditions: **(T-0).**

A2.2.10.2.1. Upon completion of installation. (Include this requirement in the construction contract as a contractor's responsibility.)

A2.2.10.2.2. After completing major repairs to any boiler component subject to steam or water pressure.

A2.2.10.2.3. Before returning boilers to service in reactivated plants.

A2.2.10.2.4. When the boiler inspector or the facility engineer recommends the test.

A2.2.10.2.5. At the frequency required in paragraph A2.2.

**Attachment 3****IMPLEMENTATION OF MAJOR AND AREA SOURCE RULES****AS APPLIED TO BOILER TUNE-UPS  
AND ENERGY ASSESSMENTS FOR THE BOILER  
NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS  
(NESHAP) RULES**

**A3.1. Purpose.** This attachment provides guidance to AFIMSC Detachments, Base Civil Engineer, Air Force boiler owners/operators, and Air Force Environmental Management offices for meeting the regulatory requirements for boiler tune-ups and energy assessments of U.S. Code of Federal Regulations, Title 40, Part 63 (40 CFR Part 63), Subparts DDDDD and JJJJJ. It is the responsibility of the Base Civil Engineer and the owners/operators of Air Force boilers to become familiar with the provisions of 40 CFR Part 63 as it pertains to their boiler systems. For further reference and details on tune-ups and energy assessments, the AFCEC/CZTQ Air Quality Subject Matter Expert provides a boiler NESHAP guide for Area Sources and a boiler (and process heater) guide for Major Sources as comprehensive guidance for compliance with 40 CFR 63 Subpart JJJJJ and Subpart DDDDD.

**A3.2. Point of Contact.** Recommendations for improvements to this guidance are encouraged. Refer recommended changes and questions regarding this AFI to the Air Force Air Quality Subject Matter Expert at AFCEC/CZTQ, 2261 Hughes Avenue Suite 155, JBSA-Lackland AFB, Texas, 78236-9853, DSN 945-3237, Commercial (210) 925-3237, e-mail: [afcec.cztq.workflow@us.af.mil](mailto:afcec.cztq.workflow@us.af.mil), using AF Form 847; route AF Forms 847 from the field through the appropriate functional chain of command.

**A3.3. Background.** The EPA published NESHAP for boilers for both Area and Major Sources on March 21, 2011. Subsequently, the EPA published amendments to the Major Source rule on January 31, 2013 and November 20, 2015, and amendments to the Area Source rule on February 1, 2013. Proposed amendments to the Area Source Rule were published in January 2015 which remains pending finalization. The regulations set requirements including tune-ups and energy assessments. This attachment provides guidance only on meeting the regulatory requirements for tune-ups and energy assessments.

**A3.4. Exemptions.**

A3.4.1. Both the Area Source rule and the Major Source rule list specific types of units which are exempt from all requirements of the rule. Exemptions from the Area Source rule are identified in 40 CFR 63.11195 and exemptions from the Major Source rule are identified in 40 CFR 63.7491. Key exemptions include the following:

A3.4.1.1. Any boiler specifically listed as, or included in the definition of, an affected source in another standard(s) under 40 CFR 63.

A3.4.1.2. A unit that burns hazardous waste covered by 40 CFR 63, Subpart EEE.

A3.4.1.3. An electric utility steam generating unit (EGU) covered by 40 CFR 63, Subpart UUUUU.

A3.4.1.4. Any boiler specifically listed as an affected source in any standard(s) established under Section 129 of the CAA (Solid Waste Combustion).

A3.4.1.5. A boiler that is used specifically for research and development. This exemption does not include boilers that solely or primarily provide steam (or heat) to a process or for heating at a research and development facility.

A3.4.1.6. Any boiler that is used as a control device to comply with another subpart under 40 CFR Parts 60, 61, 63, or 65, provided that at least 50 percent of the average annual heat input is provided by regulated gas streams that are subject to another standard.

A3.4.1.7. Temporary boilers: See Attachment 1 for definition.

A3.4.1.8. Hot water heaters: See Attachment 1 for definition.

A3.4.1.9. Residential boilers: See Attachment 1 for definition.

A3.4.2. The following additional units are also exempt specifically under the Major Source rule:

A3.4.2.1. A recovery boiler or furnace covered by 40 CFR 63, Subpart MM.

A3.4.2.2. A refining kettle covered by 40 CFR 63, Subpart X.

A3.4.2.3. An ethylene cracking furnace covered by 40 CFR 63, Subpart YY.

A3.4.2.4. Blast furnace stoves as described in EPA-453/R-01-005 (the blast furnace converts iron oxide into molten iron for subsequent refining to produce steel).

A3.4.2.5. Blast furnace gas fuel-fired boilers and process heaters: See Attachment 1 for definition.

A3.4.3. The following additional units are exempt specifically under the Area Source rule only:

A3.4.3.1. Electric boilers: See Attachment 1 for definition.

A3.4.3.2. Gas-fired boilers: See Attachment 1 for definition.

**A3.5. Requirements.** 40 CFR Part 63 stipulates operational requirements for boiler (and process heater for a Major Source) tune-ups and energy assessments for Area Source and Major Source boilers. A boiler tune-up optimizes the air-fuel mixture for the operating range of the boiler which improves combustion and reduces emissions of HAPs. Conducting an energy assessment of the boiler and boiler system identifies opportunities to improve operational efficiencies which may also result in reduction of HAP emissions. The first step is to determine the source type for the facility in regards to HAP emissions: Area Source or Major Source. Check with the base Environmental Management office to confirm the facility's source type. **Note:** The facility's source type designation (Area Source or Major Source) can be different for different pollutants; therefore, be sure to obtain the source type designation that specifically pertains to HAP emissions.

**A3.5.1. Area and Major Source Definitions Applicable to the Boiler NESHAP Rules.**

A3.5.1.1. Area Source: See Attachment 1 for definition.

A3.5.1.2. Major Source: See Attachment 1 for definition.

A3.5.2. **Tune-ups.** Boiler (and process heater for a Major Source) tune-ups are required for Area Source and Major Source boilers according to 40 CFR Part 63, Subparts JJJJJ and DDDDD. All tune-ups must be conducted following the procedures described in 40 CFR Part 63, Subpart JJJJJ, Section 63.11223 for an Area Source and 40 CFR Part 63, Subpart DDDDD, Section 63.7540 for a Major Source. **(T-0).**

A3.5.2.1. **Tune-up Applicability and Frequency .** Tune-ups on boilers (and process heaters for a Major Source) must be performed at the frequency provided in Table A3.1. **(T-0). Note:** Gas-fired boilers are exempt from tune-up and all other requirements under the Area Source rule, including dual-fuel boilers that burn liquid fuel only during periods of gas curtailment, gas supply interruption, startups, or periodic testing on liquid fuel. Periodic testing of liquid fuel must not exceed a combined total of 48 hours during any calendar year. Reference Attachment 1 for a definition of “period of gas curtailment or supply interruption.”

A3.5.2.2. **Tune-up Compliance Deadlines.** Tune-ups on boilers (and process heaters for a Major Source) must be performed per the schedule and due dates as stated in 40 CFR 63, Subpart JJJJJ and Subpart DDDDD. **(T-0).** Reference Table A3.2 for a summary of initial tune-up due dates and the schedule for subsequent tune-ups.

A3.5.2.2.1. **Initial Tune-Up Due Date .** Existing boilers (and process heater for a Major Source) (see definitions, Attachment 1, “Existing Boiler/Process Heater”) must have an initial tune-up on or before the compliance dates as stated in 40 CFR 63, Subpart JJJJJ and Subpart DDDDD. New and reconstructed boilers (and process heater for a Major Source) (see definitions, Attachment 1, “New Boiler/Process Heater” and “Reconstructed Boiler/Process Heater”) are not required to have an initial tune-up, but they must comply with their first tune-up no later than 13 months (if subject to annual tune-ups), 25 months (if subject to biennial tune-ups), or 61 months (if subject to pentennial tune-ups) after start-up, whichever is applicable. **(T-0).**

A3.5.2.2.2. . **Subsequent Tune-Up Schedule.** Tune-ups must be conducted according to the schedule stated in 40 CFR 63, Subpart JJJJJ and Subpart DDDDD. **(T-0).** The tune-up schedule is summarized in Table A3.2.

A3.5.2.2.3. **Early Tune-up .** A tune-up may be conducted early as long as the tune-up included all elements of the tune-up specified in 40 CFR 63, Subpart JJJJJ or Subpart DDDDD. If the initial tune-up for an existing boiler was completed prior to the compliance date, the next tune-up will be due no later than 13 months, 25 months, or 72 months from when the initial tune-up was conducted, as applicable. **(T-0).**

A3.5.2.2.4. **Boiler/Process Heater Not In Operation on Compliance Date.** If the boiler (or process heater for a Major Source) is not operating on the required date for a tune-up (because it is a seasonal boiler, or because it is down for maintenance, for example), the tune-up must be conducted within 30 days of startup. **(T-0).**

A3.5.2.2.5. **Burner Inspection.** Burner inspections may be performed before the tune-up or delayed until the next scheduled shutdown (scheduled or unscheduled shutdown for Major Source boilers or process heaters subject to a pentennial tune-up); however, the inspection delay may not exceed 36 months from the previous

inspection for boilers/process heaters subject to biennial tune-ups and 72 months from the previous inspection for boilers/process heaters subject to pentennial tune-ups. **(T-0)**.

**A3.5.2.2.6. Boilers or Process Heaters Located at a Major Source Where Entry Into a Piece of Process Equipment or Into a Storage Vessel Is Required.** Tune-up inspections are required only during planned entries into the storage vessel or process equipment. Remaining tune-up requirements must be met according to the applicable tune-up schedule for the unit. **(T-0)**.

**A3.5.2.3. Tune-up Notification and Reporting Deadlines.** Notification and reporting of tune-up applicability and completion must be conducted per the requirements in 40 CFR 63 Subpart JJJJJ (Area Source) and Subpart DDDDD (Major Source). **(T-0)**. Tune-up notification and reporting due dates and deadlines are summarized in Table A3.3. For boilers (and process heaters for a Major Source) subject to an initial tune-up, a signed statement indicating an initial tune-up was conducted must be included in the Notification of Compliance Status (NOC). For Area Sources, first tune-ups for new boilers and subsequent tune-ups for all boilers are reported and certified as completed in the Compliance Certification Report which is prepared by March 1<sup>st</sup> on an annual, biennial, or pentennial basis, as applicable. For Major Sources, first tune-ups for new boilers and subsequent tune-ups for all boilers are reported and certified as completed in the semi-annual Compliance Report (postmarked or submitted no later than July 31 or January 31, as applicable) or the annual, biennial, or pentennial Compliance Report (postmarked or submitted no later than January 31, as applicable). If it is determined that a tune-up compliance deadline passed, immediately contact the AFCEC/CZTQ Air Quality Subject Matter Expert for a consult on developing a compliance strategy.

**A3.5.2.4. Overview of Tune-up Requirements.** Tune-up requirements are summarized in Table A3.4 for Area Source and Major Source tune-ups. The tune-up must be conducted while burning the type of fuel (or fuels in case of units that routinely burn a mixture) that provided the majority of the heat input to the boiler or process heater over the 12 months prior to the tune-up. See referenced sections of 40 CFR Part 63 Subpart JJJJJ or Subpart DDDDD for complete requirements and details. **(T-0)**.

**Table A3.1. Tune-up Applicability and Frequency.**

	APPLICABILITY	
	AREA SOURCE (Boilers Only)	MAJOR SOURCE (Boilers and Process Heaters)
Annual (Every Year)	None	Existing or New $\geq$ 10 MMBtu/hr, Coal/Oil/Biomass/Gaseous Fuel
Biennial (Every 2 Years)	Existing $\geq$ 10 MMBtu/hr, Oil/Biomass Existing or New $>5$ and $<10$ MMBtu/hr Oil Existing or New $< 10$ MMBtu/hr, Coal/Biomass	Existing or New $< 10$ MMBtu/hr, Coal/Oil (Heavy Liquid)/Biomass Existing or New $>5$ and $<10$ MMBtu/hr Gaseous Fuel, Oil (Light Liquid)
Pentennial (Every 5 Years)	Existing or New $\leq 5$ MMBtu/hr Oil Existing or New Seasonal Existing or New Limited-Use	Existing or New $\leq 5$ MMBtu/hr, Gaseous Fuel, Oil (Light Liquid) Existing or New Limited Use
	Boilers (and process heaters for a Major Source) with an oxygen trim system that maintains an optimum air-to-fuel ratio	



Table A3.2. Tune-up Compliance Deadlines.

TUNE-UP COMPLIANCE DEADLINES		
	AREA SOURCE (Boilers Only)	MAJOR SOURCE (Boilers and Process Heaters)
<b>INITIAL TUNE-UP DEADLINES</b>		
Rule Reference	§63.11196(a)(1), (b) or (c)	§63.7495(a) or (b)
Existing Boilers/Process Heaters	Was required by 21 March 2014	Was required by 31 January 2016
	If the initial tune-up has not yet been performed (i.e., the above compliance date was missed), immediately contact the AFCEC/CZTQ Air Quality Subject Expert for a consult on developing a compliance strategy.	
New Boilers/Process Heaters	Initial tune-up by Air Force not required. New boilers/process heaters are assumed to be initially tuned up by installer/manufacturer.	
	However, the first tune-up must be conducted no later than 13 months (if subject to annual tune-ups), 25 months (if subject to biennial tune-ups), or 61 months (if subject to pentennial tune-ups) after start-up.	
<b>SUBSEQUENT TUNE-UP SCHEDULE</b>		
Rule Reference	§63.11223(b)	Annual: §63.7540(a)(10), Biennial: §63.7540(a)(11) Pentennial: §63.7540(a)(12) All: §63.7515 (d)
General	Conduct <u>biennial tune-ups</u> no more than 25 months after previous tune-up.	Conduct <u>annual tune-ups</u> no more than 13 months after previous tune-up.
		Conduct <u>biennial tune-ups</u> no more than 25 months after previous tune-up.
	Conduct <u>pentennial tune-ups</u> no more than 61 months after previous tune-up.	Conduct <u>pentennial tune-ups</u> no more than 61 months after previous tune-up.

Table A3.3. Tune-up Notification and Reporting Deadlines.

TUNE-UP NOTIFICATION & REPORTING DEADLINES		
	AREA SOURCE (Boilers Only)	MAJOR SOURCE (Boilers and Process Heaters)
<b>INITIAL NOTIFICATION (OF APPLICABILITY)</b>		
Rule Reference	§63.11225(a)(2)	§63.7545(b) and (c)
Existing Boilers/Process Heaters	Was required by 20 January 2014 or within 120 days after the boiler becomes subject to the standard.	Was required by 31 May 2014 if startup was before 31 January 2013.
New Boilers/Process Heaters		If startup is on or after 31 January 2013, then within 15 days after startup.
<b>INITIAL TUNE-UP NOTICE OF COMPLIANCE (NOC) STATUS*</b>		
Rule Reference	§63.11225(a)(4)	§63.7545(e)
Existing Boilers/Process Heaters	Was required by 19 July 2014 (or within 60 days of stack test, if required).	To be submitted within 60 days following the completion of all compliance demonstrations, including performance test results and fuel analyses, for all boiler or process heaters at the facility.
New Boilers/Process Heaters	NOC not required for tune-ups.	
<b>SUBSEQUENT TUNE-UP REPORTING &amp; DUE DATE*</b>		
Rule Reference	§63.11225(b)	§63.7545(e)
Existing Boilers/Process Heaters	Tune-up reporting to be included in the Certificate of Compliance which must be prepared by March 1 <sup>st</sup> , on an annual, biennial, or pentennial basis, as applicable.	Tune-up reporting to be included in the Compliance Report which must be prepared on a semi-annual, annual, biennial, or pentennial basis, as applicable.
New Boilers/Process Heaters		
*If a notice or report was not submitted by the due date, immediately contact the AFCEC/CZTQ Air Quality Subject Expert for a consult on developing a compliance strategy.		

**Table A3.4. Tune-up Requirements.**

	<b>TUNE-UP REQUIREMENTS</b>	
	<b>AREA SOURCE (Boilers Only)</b>	<b>MAJOR SOURCE (Boilers and Process Heaters)</b>
Rule Reference	<i>§63.11223</i>	<i>§63.7540</i>
Tune-up Requirements	<p>1. The tune-up must be conducted while burning the type of fuel (or fuels in case of units that routinely burn a mixture) that provided the majority of the heat input to the boiler (or process heater for a Major Source) over the 12 months prior to the tune-up.</p> <p>2. As applicable, inspect the burner and clean or replace any components of the burner as necessary (you may delay the burner inspection until the next scheduled unit shutdown, but you must inspect each burner at least once every 36 months).</p> <p>3. Inspect the flame pattern, as applicable, and adjust the burner as necessary to optimize the flame pattern. The adjustment should be consistent with the manufacturer's specifications, if available.</p> <p>4. Inspect the system controlling the air-to-fuel ratio, as applicable, and ensure that it is correctly calibrated and functioning properly.</p> <p>5. Optimize total emissions of carbon monoxide. This optimization should be consistent with the manufacturer's specifications, if available.</p> <p>6. Measure the concentrations in the effluent stream of carbon monoxide in parts per million, by volume, and oxygen in volume percent, before and after the adjustments are made. (Measurements may be either on a dry or wet basis, as long as it is the same basis before and after the adjustments are made.)</p>	
	<p>7. Maintain records onsite and submit, if requested by the EPA administrator, a biennial report containing the information below:</p> <p>(i) The concentrations of carbon monoxide (CO) in the effluent stream in parts per million, by volume, and oxygen in volume percent, measured before and after the tune-up of the boiler.</p> <p>(ii) A description of any corrective actions taken as a part of the tune-up of the boiler.</p> <p>(iii) The type and amount of fuel used over the 12 months prior to the tune-up of the boiler.</p>	<p>7. Maintain records on-site and submit, if requested by the EPA administrator, an annual report containing the information below:</p> <p>(i) The concentrations of carbon monoxide (CO) in the effluent stream in parts per million by volume, and oxygen in volume percent, measured before and after the adjustments of the boiler.</p> <p>(ii) A description of any corrective actions taken as a part of the combustion adjustment.</p> <p>(iii) The type and amount of fuel used over the 12 months prior to the annual adjustment, but only if the unit was physically and legally capable of using more than one type of fuel during that period. Units sharing a fuel meter may estimate the fuel use by each unit.</p>
	<p>8. If the unit is not operating on the required date for a tune-up, the tune-up must be conducted within 30 days of startup.</p>	

**A3.5.3. Energy Assessments.** Energy assessments are a one-time requirement for existing Area Source and Major Source boilers according to 40 CFR Part 63, Subpart JJJJJ and Subpart DDDDD. The Area Source and Major Source energy assessment requirements are summarized in Table A3.5 through Table A3.9. See referenced sections of 40 CFR Part 63 for complete requirements and details.

**A3.5.3.1. Purpose of Energy Assessment.** The energy assessment's purpose is to identify energy conservation measures (e.g., process changes or other modifications to the facility) that can be implemented to reduce system and facility energy demand which

would reduce fuel use and emissions. Note: the EPA does not require that the facility implement energy conservation measures identified by the assessment.

**A3.5.3.2. Energy Assessment Applicability.** Energy assessments are required for both Area Sources and Major Sources. Energy assessment applicability is summarized in Table A3.5.

**A3.5.3.2.1. Area Sources.** Assessments are required for existing boilers only (not process heaters),  $\geq 10$  MMBtu/hr in size, using coal/oil/biomass fuel (not gas). This is a one-time requirement. Exception: Energy assessments are not required for existing limited-use boilers.

**A3.5.3.2.2. Major Sources.** Assessments are required only for existing boilers and process heaters of any size, using any fuel (coal/oil/biogas/gas 1 or gas 2). This is a one-time requirement. Exception: Energy assessments are not required for existing limited-use boilers.

**A3.5.3.3. Compliance Dates for Energy Assessments.** Compliance deadlines are summarized in Table A3.6. Energy assessment notification and reporting due dates are summarized in Table A3.7.

**A3.5.3.4. Prior Assessments.** Energy assessments completed on or after 1 January 2008, that include the criteria of Table 2 to Subpart JJJJJ and Table 3 to Subpart DDDDD of 40 CFR Part 63 can be used to satisfy the energy assessment requirement. Energy assessor approval and qualification requirements are waived in instances where past or amended energy assessments are used. Per 40 CFR, the Base Civil Engineer will determine if the prior assessment meets the criteria before submitting to the EPA. **(T-0)**. If part of the requirements conducted under the prior assessment is lacking, the remaining tasks can be completed and then submitted along with the previous assessment.

**Table A3.5. Energy Assessment Applicability.**

ENERGY ASSESSMENT APPLICABILITY		
	AREA SOURCE (EXISTING BOILERS ONLY)	MAJOR SOURCE (EXISTING BOILERS AND PROCESS HEATERS ONLY)
Rule Reference	<i>§63.11210(j)(3); Table 2 to 40 CFR 63 Subpart JJJJJ</i>	<i>§63.7510(e) and Table 3 to 40 CFR Subpart DDDDD</i>
Size	$\geq 10$ MMBtu/hr	Any Size
Fuel Category	Coal/oil/biomass ( <b>not</b> gas), not including limited use units	<b>Any</b> fuel: Coal/oil/biomass/gas 1 or 2 (not including limited use units)

**Table A3.6. Energy Assessment Compliance Deadline.**

ENERGY ASSESSMENT COMPLIANCE DEADLINES		
	AREA SOURCE (Boilers Only)	MAJOR SOURCE (Boilers and Process Heaters)
Rule Reference	<i>§63.11196(a)(3)</i>	<i>§63.7495(b)</i>
Compliance Date	Was required by 21 March 2014	Was required by 31 January 2016
	If the energy assessment was not performed (i.e., the above compliance date was missed), immediately contact the AFCEC/CZTQ Air Quality Subject Expert for a consult on developing a compliance strategy.	

**Table A3.7. Energy Assessment Notification and Reporting Due Dates.**

<b>ENERGY ASSESSMENT NOTIFICATION &amp; REPORTING DUE DATES</b>		
	<b>AREA SOURCE (Boilers Only)</b>	<b>MAJOR SOURCE (Boilers and Process Heaters)</b>
<b>INITIAL NOTIFICATION (OF APPLICABILITY)*</b>		
Rule Reference	§63.11225(a)(2)	§63.7545(b)
Due Date	Was required by 20 January 2014 or within 120 days after the existing boiler becomes subject to the standard, whichever is later.	Was required by 31 May 2014 if startup was before 31 January 2013.  If startup is on or after 31 January 2013, then within 15 days after startup.
<b>INITIAL NOTICE OF COMPLIANCE (NOC) STATUS*</b>		
Rule Reference	§63.11225(a)(4)	§63.7545(e)
Due Date	Was required by 19 July 2014 (or within 60 days of stack test, if required)	To be submitted within 60 days following the completion of <u>all</u> compliance demonstrations, including performance test results and fuel analyses, for <u>all</u> boiler or process heaters at the facility.
*If a notice or report was not submitted by the due date, immediately contact the AFCEC/CZTQ Air Quality Subject Expert for a consult on developing a compliance strategy.		

**Table A3.8. Energy Assessment Requirements.**

<b>ENERGY ASSESSMENT REQUIREMENTS</b>		
	<b>AREA SOURCE (Boilers Only)</b>	<b>MAJOR SOURCE (Boilers and Process Heaters)</b>
Rule Reference	Table 2 to Subpart JJJJJ (40 CFR 63)	Table 3 to Subpart DDDDD (40 CFR 63)
General	A one-time energy assessment must be performed by a qualified energy assessor (see definition in Attachment 1).	
	An energy assessment completed on or after 1 January 2008, that meets or is amended to meet the energy assessment requirements in this table, satisfies the energy assessment requirement. A facility that operated under an energy management program developed according to the ENERGY STAR guidelines for energy management or compatible with ISO 50001 for at least one year between 1 January 2008 and the compliance date that includes the affected units also satisfies the energy assessment requirement. The energy assessment must meet the extent of the evaluation appropriate for the on-site technical hours.	
Energy Assessment Requirements	1. A visual inspection of the boiler system.	
	2. An evaluation of operating characteristics of the facility, specifications of energy-using systems, operating and maintenance procedures, and unusual operating constraints.	
	3. Inventory of major systems consuming energy from affected boiler(s).	
	4. A review of available architectural and engineering plans, facility operation and maintenance procedures and logs, and fuel usage.	
	5. A list of major energy conservation measures.	
	6. Not included for Area Sources	6. A review of the facility's energy management practices and provide recommendations for improvements consistent with the definition of energy management practices.
	7. A list of the energy savings potential of the identified energy conservation measures.	
	8. A comprehensive report detailing the ways to improve efficiency, the cost of specific improvements, benefits, date of assessment, and the time frame for recouping those investments.	

**Table A3.9. Scope and Duration of Energy Assessment.**

Rule Reference	SCOPE AND DURATION OF ENERGY ASSESSMENT	
	AREA SOURCE (Boilers Only)	MAJOR SOURCE (Boilers and Process Heaters)
	§63.11237	§63.7575
Combined heat input capacity < 0.3 TBtu/yr	1. Energy assessment for facilities with affected boilers using <u>less than 0.3 trillion Btu (TBtu) per year heat input</u> will be <b>8 hours onsite technical labor hours in length maximum*</b> . The boiler (or process system(s) for a Major Source), process heater(s), and any on-site energy use system(s)** accounting for at least 50 percent of the affected unit(s) energy (e.g., steam, hot water, process heat, or electricity) production, as applicable, will be evaluated to identify energy savings opportunities, within the limit of performing an 8-hour on-site energy assessment. (See Attachment 1 for definition.)	
Combined heat input capacity of 0.3 to 1 TBtu/yr	2. Energy assessment for facilities with affected boilers and process heaters using <u>0.3 to 1 TBtu/year</u> will be <b>24 hours onsite technical labor hours in length maximum*</b> . The boiler (or process system(s) for a Major Source), process heater(s), and any on-site energy use system(s)** accounting for at least 33 percent of the affected unit(s) energy (e.g., steam, hot water, process heat, or electricity) production, as applicable, will be evaluated to identify energy savings opportunities, within the limit of performing an 8-hour on-site energy assessment. (See Attachment 1 for definition.)	
Combined heat input capacity > 1 TBtu/yr	3. Energy assessment for facilities with affected boilers and process heaters using <u>greater than 1.0 TBtu/year</u> will be <b>24 hours onsite technical labor hours in length maximum, plus 8 hours for each additional 1.0 TBtu/yr (not to exceed 160 hours)*</b> . The boiler (or process system(s) for a Major Source), process heater(s), and any on-site energy use system(s)** accounting for at least 20 percent of the affected unit(s) energy (e.g., steam, hot water, process heat, or electricity) production, as applicable, will be evaluated to identify energy savings opportunities, within the limit of performing an 8-hour on-site energy assessment. (See Attachment 1 for definition.)	
	*At the discretion of the facility, the duration of the energy assessment can exceed the maximum number of onsite technical labor hours. **The on-site energy use systems serving as the basis for the percent of affected boiler(s) (and process heater(s) for a Major Source) energy production may be segmented by production area or energy use area as most logical and applicable to the specific facility being assessed (e.g., product X manufacturing area; product Y drying area; Building Z).	
<b>IMPORTANT! - CLARIFICATIONS ABOUT SCOPE AND DURATION</b>		
The heat input cut-off values apply to the <b>combined heat input</b> of all the affected boilers (and process heaters, if a major source facility). For example, if there are 10 boilers at the facility and they are individually less than 0.3 TBtu/yr but their combined heat input is greater than 1 TBtu/yr, then the facility would be considered to be in the > 1 TBtu/yr category to determine the duration and scope of the energy assessment.		
The energy assessment must <b>include all of the affected boiler systems</b> (see definition in Attachment 1). For example, if you have 10 affected boilers in your facility then you will likely have to assess ten boiler systems.  The requirement is that the energy assessment must include, in addition to the affected boiler system, some percent of the systems using the energy from the affected boilers. That percent will be 50, 33, or 20 percent, depending on the heat input category identified for the facility. For example, if the facility is in the > 1 TBtu/yr heat input category, and there is one boiler that serves ten buildings, then the energy assessment should include the boiler system and any of the ten buildings that would be using at least 33% of the energy from that boiler system. If none of the buildings are using at least 33% of the energy, then only the boiler system would be included in the energy assessment.		

**A3.5.4. Notification, Reporting, and Recordkeeping Requirements.** 40 CFR Part 63, Subpart JJJJJ and Subpart DDDDD includes notification, reporting, and recordkeeping requirements for both Area Source and Major Source boilers. Notifications and reports also involve other requirements which require coordination and consultation with the Base Civil Engineer Environmental function's Air Quality Program Manager.

**A3.5.4.1. Area Source.** Area Source notification, reporting, and recordkeeping requirements are listed in 40 CFR Part 63, Subpart JJJJJ, Section 63.11225. The notification and reporting due dates are summarized in Table A3.3 and Table A3.7. Notification, reporting, and recordkeeping requirements related to both tune-ups and energy assessments are summarized below.

A3.5.4.1.1. Submit an “Initial Notification of Applicability” form (required under 40 CFR 63.9(b) and 63.11225(a)(2)) to the appropriate State agency if it has been delegated the authority for this regulation under section 112(l) of the CAA. If the state has not been delegated the authority for this rule, submit the notification to the appropriate EPA regional office. EPA regional office addresses are provided in 40 CFR 63.13. The notice must be signed by a responsible official (paragraph 2.5, “Installation Commander”). **(T-0)**. Download a sample “Initial Notification of Applicability” form at:

[http://www.epa.gov/ttn/atw/boiler/imptools/area\\_initial\\_notification.doc](http://www.epa.gov/ttn/atw/boiler/imptools/area_initial_notification.doc).

A3.5.4.1.2. Submit the following compliance reports to the EPA for boilers subject to a tune-up and/or energy assessment. **(T-0)**.

A3.5.4.1.2.1. A NOC Status report is required under 40 CFR 63.9(h) and 63.11225(a)(4) for all existing boilers. The report must be signed by a responsible official (paragraph 2.5, “Installation Commander”) and state “This facility complies with the requirements in §63.11214 to conduct an initial tune-up of the boiler.” In addition, for existing boilers with a heat input capacity of 10 MMBtu/hr or greater, the NOC Status report must state, “This facility has had an energy assessment performed according to §63.11214(c).” The NOC Status report must be submitted electronically using the Compliance and Emissions Data Reporting Interface (CEDRI) that is accessed through EPA’s Central Data Exchange (CDX) ([www.epa.gov/cdx](http://www.epa.gov/cdx)). **Note:** the electronic version of the NOC Status report for Area Sources became available in CEDRI on 1 January 2014. Prior to that date, the EPA allowed submission of a written NOC Status report for Area Sources and there is no requirement to resubmit the report electronically. **(T0)**.

A3.5.4.1.2.2. A Compliance Certification Report must be prepared (and submitted to the EPA or delegated authority upon request) by March 1<sup>st</sup> of the year following the calendar year during which a biennial or 5-year tune-up is completed for boilers not subject to emission or operating limits. To comply with 40 CFR 63.11225(b), the Compliance Certification Report must be signed by a responsible official (paragraph 2.5, “Installation Commander”) and include a statement, “This facility complies with the requirements in §63.11223 to conduct a biennial or 5-year tune-up, as applicable, of each boiler.” **(T-0)**.

A3.5.4.1.3. Recordkeeping requirements associated with Area Source boilers are specified in 40 CFR 63.11225(c). Requirements related to tune-ups and energy assessments include the following:

A3.5.4.1.3.1. A copy must be kept of each notification and report that was submitted to comply with Subpart JJJJJ and all documentation supporting any Initial Notification or NOC status that was submitted. Notification using the NOC status report must be accomplished as described in paragraph A3.5.4.1.2. **(T-0)**.

A3.5.4.1.3.2. Records must be kept to document conformance with the work practices and management practices required by 40 CFR 63.11214 and 63.11223, including boiler tune-up and energy assessment requirements. **(T-0)**.

A3.5.4.1.3.3. For boilers requiring tune-ups, records must identify each boiler (include National Board Number and also operating permit number, if applicable), the date of tune-up, the procedures followed for tune-up, and the manufacturer's specifications to which the boiler was tuned. **(T-0)**.

A3.5.4.1.3.4. For each boiler required to conduct an energy assessment, a copy must be kept of the energy assessment report. A copy of the report is not required to be submitted to the EPA. **(T-0)**.

A3.5.4.1.3.5. All records must be in a form suitable and readily available for expeditious review. Each record must be kept for five (5) years following the date of each recorded action. Each record must be kept on-site or be accessible from a central location by computer or other means that instantly provides access at the site for at least two (2) years after the date of each recorded action. If desired, records may be kept off-site for the remaining three (3) years. **(T-0)**.

A3.5.4.1.4. All records/documents associated with Subpart JJJJJ compliance must also be uploaded into the Air Program Information Management System (APIMS) to comply with AFI 32-7040, which requires all air quality compliance and resource management data to be accurately maintained in APIMS by the installation environmental function. **(T-1)**.

A3.5.4.2. **Major Source.** Major Source notification, reporting, and recordkeeping requirements are listed in 40 CFR Part 63, Subpart DDDDD, sections 63.7545 through 63.7560. The notification and reporting due dates are summarized in Table A3.3, Table A3.7, and Table A3.10. Requirements related to tune-ups and energy assessments are summarized below.

A3.5.4.2.1. Submit an Initial Notification of Applicability form (required under 40 CFR 63.9(b), 63.7545(b), and 63.7545(c)) to the appropriate State agency if it has been delegated the authority for this regulation under section 112(l) of the CAA. If the state has not been delegated the authority for this rule, submit the notification to the appropriate EPA Regional Office. EPA regional office addresses are provided in 40 CFR 63.13. The notification must be signed by a responsible official (paragraph 2.5, "Installation Commander"). **(T-0)**.

A3.5.4.2.2. Submit the following compliance reports to the EPA for boilers and process heaters subject to tune-up and energy assessment requirements. **(T-0)**.

A3.5.4.2.2.1. A NOC status report is required under 40 CFR 63.9(h) and 63.7545(e) for existing boilers with a submission to the EPA no later than before close of business on the 60<sup>th</sup> day following the completion of all performance tests

and/or other initial compliance demonstrations required under 40 CFR 63.7530. The report must be signed by a responsible official (paragraph 2.5, “Installation Commander”) and state, “This facility completed the required initial tune-up for all of the boilers and process heaters covered by 40 CFR part 63 subpart DDDDD at this site according to the procedures in section 63.7540(a)(10)(i) through (vi) and has had an energy assessment performed according to §63.7530(e).” **(T-0)**.

A3.5.4.2.2.2. A Compliance Report must be prepared for boilers and process heaters that conducted an annual, biennial, or five-year tune-up the previous calendar year and are not subject to emission or operating limits. Boilers and process heaters subject to emission or operating limits are required to report semi-annually. To comply with 40 CFR 63.11225(b), the Compliance Report must be signed by a responsible official (paragraph 2.5, “Installation Commander”) and include a statement, “This facility complies with the requirements in §63.11223 to conduct a biennial or 5-year tune-up, as applicable, of each boiler.” **(T-0)**.

**Table A3.10. Summary of Due Dates for Compliance Reports.**

Required Report Frequency	Report Due Date	Covering
Semi-annual	31 July of each year	1 January through 30 June of each year
	31 January of each year	1 July through 31 December of each year
Annual	31 January of each year	1 January to 31 December of each year
Biennial	31 January of every other year	The 2-year period from 1 January to 31 December
5-Year	31 January of every fifth year	The 5-year period from 1 January to 31 December

A3.5.4.2.3. Recordkeeping requirements associated with Major Source boilers are specified in 40 CFR 63.7555 and 63.7560. Requirements related to tune-ups and energy assessments include the following:

A3.5.4.2.3.1. A copy must be kept of each notification and report that was submitted to comply with Subpart DDDDD and all documentation supporting any Initial Notification or Notification of Compliance Status or Compliance Report that was submitted. **(T-0)**.

A3.5.4.2.3.2. All records must be in a form suitable and readily available for expeditious review. Each record must be kept for five (5) years following the date of each report or record. Each record must be kept on-site or be accessible from on-site (for example, through a computer network) for at least two (2) years after the date of each report or record. If desired, records may be kept off site for the remaining three years. **(T-0)**.

A3.5.4.2.4. All records/documents associated with Subpart DDDDD compliance must also be uploaded into APIMS to comply with AFI 32-7040, which requires all air quality compliance and resource management data to be accurately maintained in APIMS by the installation Environmental function. **(T-1)**.



## Attachment 4

### TUNING BOILERS FOR MAXIMUM EFFICIENCY

**A4.1. General.** The following combustion efficiency tables can be used to tune natural gas and oil-fired, condensing and non-condensing, steam and hot water boilers. **Note:** Area and Major Source boiler tune-up procedures are described in 40 CFR 63.11223(b) and 40 CFR 63.7540(a)(10), respectively. The tables are divided by fuel type, high heating value (HHV) of the fuel, and by outside ambient temperature. These parameters vary between typical limits and should reasonably reflect actual field conditions at various times of the year. All tables are calibrated for standard sea level pressure (14.696 psia). These tables are for reference use only, as it is difficult to capture all variables affecting a boiler's operating combustion efficiency (e.g., fuel impurities, burner condition, firing rate). However, the tables do provide accurate trend information.

**A4.2. Combustion Efficiency Parameters .** Measured parameters required to use these tables are listed in paragraphs A4.2.1 through A4.2.5. Extrapolating table data outside these ranges is not advised; using the tables at pressure altitudes exceeding 1500 feet above sea level is also not recommended.

A4.2.1. Boiler type (condensing or non-condensing).

A4.2.2. High heating value (HHV) of the fuel.

A4.2.2.1. 980 – 1080 Btu/ft<sup>3</sup> for natural gas.

A4.2.2.2. 131,500 – 139,600 Btu/gal for fuel oil.

A4.2.3. Flue stack temperature between 90 and 640 °F.

A4.2.4. Excess O<sub>2</sub> between 0 and 15% (or a corresponding excess air percentage).

A4.2.5. Outside ambient temperature between 20 and 40 °F.

### **A4.3. Measuring Combustion Efficiency Using Tables .**

A4.3.1. First, determine the HHV for the fuel you are using. This information is usually indicated on the utility or fuel purchase invoice. If not, contact your utility supplier for this information, or use the intermediate table value (1,030 Btu/ft<sup>3</sup> for natural gas; 135,500 Btu/gal for #2 fuel oil).

A4.3.2. Second, determine the ambient air temperature. This is the temperature of the air entering the boiler. Outside air temperature may be used if the internal boiler/mechanical room heat gains are small.

A4.3.3. Third, determine if the boiler is a condensing or non-condensing boiler. This information should be clearly indicated in the manufacturer's O&M manual.

A4.3.4. Next, using a calibrated portable combustion analyzer, measure and record the temperature and O<sub>2</sub> concentrations in the flue duct. Use the sampling procedures described in ASME Code PTC 19.10-1981, Section 3. Use a minimum of eight sampling points to ensure the velocity is uniform in each area of the duct.

A4.3.5. Finally, calculate and record the temperature difference between the flue gas and the ambient temperature ( $\Delta T$ ). Using the information previously gathered, find the appropriate combustion efficiency values from the table(s). Interpolation between values is permissible.

**A4.4. Adjusting Combustion Air Trim.** The combustion air should always be set within the range specified by the manufacturer. If the range is specified in terms of excess  $O_2$ , then use the flue gas readings from the combustion analyzer. If the range is specified in terms of excess air, then use the tables to cross-reference the excess air value based on the excess  $O_2$  reading.

**A4.4.1. Outside Air Temperature.** Air temperature is inversely proportional to air density. As the outside air temperature decreases, the air density increases. For boiler systems using fixed combustion air intakes (such as venturi air intakes), increased air density causes the excess air rate to increase (decreasing combustion efficiency). A temperature swing of  $\pm 50$  °F can cause a fluctuation of up to 35% in excess air. To mitigate this effect, the combustion air should be adjusted to the minimum excess air limit at the corresponding highest operational outside air temperatures. For example, consider a boiler with a fixed venturi air intake and a manufacturer's recommended excess air range of 20–60%. Assuming the boiler is expected to be firing at outside air temperatures from 0–50 °F, the venturi air intake should be set for minimum excess air (20%) while the outside air temperature is at or near a maximum (50 °F). This procedure assures that the boiler will still fire inside the appropriate range when the outside air temperature is 0 °F. Boilers using automatic combustion air control regulators (i.e., excess  $O_2$  flue gas sensors) are not affected by outside air temperature.

**A.4.2.2. Flue Stack Temperature.** Flue gas (or stack) temperatures are driven by the temperature of the boiler supply water (or steam) and the efficiency of the heat transfer across the boiler's internal heat exchanger (i.e., tube bundle). Flue stack temperatures are always greater than the water/steam supply temperature due to heat losses. To increase boiler efficiency, the supply temperature should be set to the lowest temperature that will satisfy the load. Flue stack temperatures that rise over time (while the supply set point remains constant) may indicate fouling of the internal heat exchanger or tube bundle. In this case, the boiler should be scheduled for shutdown and heat exchanger cleaning.

**A4.5. List of Tables** Table A4-1a: Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [70°F ≤ ΔT ≤ 120°F]

- Table A4-1b: Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-2a: Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [60°F ≤ ΔT ≤ 110°F]  
 Table A4-2b: Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-3a: Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [50°F ≤ ΔT ≤ 100°F]  
 Table A4-3b: Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-4a: Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [70°F ≤ ΔT ≤ 120°F]  
 Table A4-4b: Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-5a: Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [60°F ≤ ΔT ≤ 110°F]  
 Table A4-5b: Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-6a: Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [50°F ≤ ΔT ≤ 100°F]  
 Table A4-6b: Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-7a: Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [70°F ≤ ΔT ≤ 120°F]  
 Table A4-7b: Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-8a: Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [60°F ≤ ΔT ≤ 110°F]  
 Table A4-8b: Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-9a: Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [50°F ≤ ΔT ≤ 100°F]  
 Table A4-9b: Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-10a: #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [T<sub>(ambient)</sub> = 20°F]; [70°F ≤ ΔT ≤ 120°F]  
 Table A4-10b: #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-11a: #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [T<sub>(ambient)</sub> = 30°F]; [60°F ≤ ΔT ≤ 110°F]  
 Table A4-11b: #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [T<sub>(ambient)</sub> = 30°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-12a: #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [T<sub>(ambient)</sub> = 40°F]; [50°F ≤ ΔT ≤ 100°F]  
 Table A4-12b: #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [T<sub>(ambient)</sub> = 40°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-13a: #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [T<sub>(ambient)</sub> = 20°F]; [70°F ≤ ΔT ≤ 120°F]  
 Table A4-13b: #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-14a: #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [T<sub>(ambient)</sub> = 30°F]; [60°F ≤ ΔT ≤ 110°F]  
 Table A4-14b: #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [T<sub>(ambient)</sub> = 30°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-15a: #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [T<sub>(ambient)</sub> = 40°F]; [50°F ≤ ΔT ≤ 100°F]  
 Table A4-15b: #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [T<sub>(ambient)</sub> = 40°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-16a: #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [T<sub>(ambient)</sub> = 20°F]; [70°F ≤ ΔT ≤ 120°F]  
 Table A4-16b: #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-17a: #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [T<sub>(ambient)</sub> = 30°F]; [60°F ≤ ΔT ≤ 110°F]  
 Table A4-17b: #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [T<sub>(ambient)</sub> = 30°F]; [125°F ≤ ΔT ≤ 600°F]  
 Table A4-18a: #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [T<sub>(ambient)</sub> = 40°F]; [50°F ≤ ΔT ≤ 100°F]  
 Table A4-18b: #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [T<sub>(ambient)</sub> = 40°F]; [125°F ≤ ΔT ≤ 600°F]

**Table A4.1a. Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [70°F ≤ ΔT ≤ 120°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 70°F		ΔT = 80°F		ΔT = 90°F		ΔT = 100°F		ΔT = 110°F		ΔT = 120°F	
				η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing
138.02	0.00	0.00	12.07	88.62	96.12	88.41	94.95	88.20	93.51	87.99	91.77	87.78	89.64	87.57	87.57
137.26	2.20	0.50	11.78	88.59	96.04	88.38	94.85	88.17	93.39	87.95	91.61	87.74	89.44	87.52	87.52
136.49	4.50	1.00	11.50	88.57	95.96	88.35	94.74	88.13	93.25	87.91	91.44	87.69	89.23	87.47	87.47
135.69	6.93	1.50	11.21	88.53	95.88	88.31	94.63	88.09	93.11	87.87	91.26	87.64	89.01	87.42	87.42
134.87	9.48	2.00	10.92	88.50	95.78	88.28	94.51	88.05	92.97	87.82	91.08	87.59	88.78	87.36	87.36
134.03	12.18	2.50	10.63	88.47	95.69	88.24	94.39	88.00	92.81	87.77	90.88	87.54	88.53	87.31	87.31
133.16	15.02	3.00	10.35	88.43	95.59	88.20	94.26	87.96	92.65	87.72	90.68	87.48	88.27	87.24	87.24
132.27	18.02	3.50	10.06	88.40	95.48	88.15	94.13	87.91	92.47	87.67	90.46	87.42	88.00	87.18	87.18
131.35	21.20	4.00	9.77	88.36	95.37	88.11	93.98	87.86	92.29	87.61	90.23	87.36	87.71	87.11	87.11
130.4	24.57	4.50	9.48	88.31	95.25	88.06	93.83	87.80	92.10	87.55	89.98	87.29	87.40	87.04	87.04
129.43	28.16	5.00	9.20	88.27	95.12	88.01	93.66	87.75	91.89	87.48	89.72	87.22	87.22	86.96	86.96
128.42	31.97	5.50	8.91	88.22	94.98	87.95	93.49	87.68	91.67	87.42	89.44	87.15	87.15	86.88	86.88
127.37	36.04	6.00	8.62	88.17	94.84	87.89	93.31	87.62	91.43	87.34	89.15	87.07	87.07	86.79	86.79
126.3	40.39	6.50	8.33	88.11	94.68	87.83	93.11	87.55	91.18	87.27	88.83	86.98	86.98	86.70	86.70
125.18	45.05	7.00	8.05	88.06	94.52	87.76	92.90	87.47	90.91	87.18	88.49	86.89	86.89	86.60	86.60
124.02	50.05	7.50	7.76	87.99	94.34	87.69	92.67	87.39	90.62	87.09	88.13	86.79	86.79	86.49	86.49
122.82	55.45	8.00	7.47	87.93	94.15	87.62	92.42	87.31	90.31	86.99	87.73	86.68	86.68	86.37	86.37
121.57	61.27	8.50	7.18	87.85	93.94	87.53	92.16	87.21	89.98	86.89	87.31	86.57	86.57	86.25	86.25
120.27	67.57	9.00	6.90	87.77	93.71	87.44	91.87	87.11	89.61	86.78	86.85	86.44	86.44	86.11	86.11
118.91	74.43	9.50	6.61	87.69	93.47	87.34	91.56	87.00	89.22	86.65	86.65	86.31	86.31	85.96	85.96
117.5	81.91	10.00	6.32	87.59	93.20	87.24	91.22	86.88	88.79	86.52	86.52	86.16	86.16	85.80	85.80
116.02	90.10	10.50	6.04	87.49	92.91	87.12	90.84	86.75	88.31	86.37	86.37	86.00	86.00	85.63	85.63
114.47	99.11	11.00	5.75	87.38	92.59	86.99	90.43	86.60	87.79	86.21	86.21	85.82	85.82	85.43	85.43
112.85	109.07	11.50	5.46	87.25	92.24	86.85	89.98	86.44	87.22	86.03	86.03	85.63	85.63	85.22	85.22
111.13	120.13	12.00	5.17	87.11	91.84	86.69	89.48	86.26	86.58	85.83	85.83	85.41	85.41	84.98	84.98
109.33	132.50	12.50	4.89	86.96	91.40	86.51	88.92	86.06	86.06	85.61	85.61	85.16	85.16	84.71	84.71
107.42	146.41	13.00	4.60	86.78	90.90	86.31	88.28	85.84	85.84	85.36	85.36	84.89	84.89	84.41	84.41
105.39	162.18	13.50	4.31	86.59	90.34	86.08	87.56	85.58	85.58	85.08	85.08	84.58	84.58	84.07	84.07
103.23	180.20	14.00	4.02	86.36	89.70	85.82	86.74	85.29	85.29	84.76	84.76	84.22	84.22	83.68	83.68
100.92	200.99	14.50	3.74	86.10	88.96	85.53	85.80	84.95	84.95	84.38	84.38	83.81	83.81	83.24	83.24
98.43	225.25	15.00	3.45	85.79	88.10	85.18	85.18	84.56	84.56	83.95	83.95	83.33	83.33	82.71	82.71

**Table A4.1b. Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
138.02	0.00	0.00	12.07	87.46	86.93	86.40	85.87	85.33	84.80	83.72	82.63	81.54	80.43	79.32	77.08
137.26	2.20	0.50	11.78	87.41	86.87	86.33	85.79	85.24	84.70	83.60	82.49	81.38	80.26	79.12	76.84
136.49	4.50	1.00	11.50	87.36	86.81	86.26	85.71	85.15	84.59	83.47	82.35	81.21	80.07	78.91	76.58
135.69	6.93	1.50	11.21	87.31	86.75	86.18	85.62	85.05	84.48	83.34	82.19	81.03	79.87	78.69	76.32
134.87	9.48	2.00	10.92	87.25	86.68	86.10	85.53	84.95	84.37	83.20	82.03	80.85	79.66	78.46	76.04
134.03	12.18	2.50	10.63	87.19	86.60	86.02	85.43	84.84	84.25	83.06	81.86	80.65	79.44	78.21	75.74
133.16	15.02	3.00	10.35	87.12	86.53	85.93	85.33	84.72	84.12	82.90	81.68	80.45	79.21	77.96	75.43
132.27	18.02	3.50	10.06	87.06	86.45	85.83	85.22	84.60	83.98	82.74	81.49	80.23	78.96	77.68	75.10
131.35	21.20	4.00	9.77	86.99	86.36	85.73	85.10	84.47	83.84	82.57	81.29	80.00	78.70	77.39	74.75
130.4	24.57	4.50	9.48	86.91	86.27	85.63	84.98	84.34	83.69	82.39	81.07	79.75	78.42	77.09	74.38
129.43	28.16	5.00	9.20	86.83	86.17	85.51	84.85	84.19	83.53	82.19	80.85	79.49	78.13	76.76	73.98
128.42	31.97	5.50	8.91	86.74	86.07	85.39	84.72	84.04	83.36	81.99	80.61	79.22	77.82	76.41	73.56
127.37	36.04	6.00	8.62	86.65	85.96	85.27	84.57	83.87	83.17	81.77	80.35	78.92	77.49	76.04	73.12
126.3	40.39	6.50	8.33	86.56	85.84	85.13	84.41	83.70	82.98	81.53	80.07	78.61	77.13	75.64	72.64
125.18	45.05	7.00	8.05	86.45	85.72	84.98	84.25	83.51	82.77	81.28	79.78	78.27	76.75	75.22	72.13
124.02	50.05	7.50	7.76	86.34	85.58	84.83	84.07	83.30	82.54	81.01	79.46	77.91	76.34	74.76	71.58
122.82	55.45	8.00	7.47	86.22	85.44	84.66	83.87	83.09	82.30	80.71	79.12	77.51	75.90	74.27	70.98
121.57	61.27	8.50	7.18	86.09	85.28	84.47	83.66	82.85	82.04	80.40	78.75	77.09	75.42	73.74	70.34
120.27	67.57	9.00	6.90	85.94	85.11	84.27	83.44	82.59	81.75	80.06	78.35	76.63	74.91	73.17	69.65
118.91	74.43	9.50	6.61	85.79	84.93	84.06	83.19	82.32	81.44	79.69	77.92	76.14	74.35	72.54	68.90
117.5	81.91	10.00	6.32	85.62	84.72	83.82	82.92	82.01	81.11	79.28	77.44	75.59	73.73	71.86	68.07
116.02	90.10	10.50	6.04	85.44	84.50	83.57	82.63	81.68	80.74	78.84	76.92	75.00	73.06	71.11	67.17
114.47	99.11	11.00	5.75	85.24	84.26	83.28	82.30	81.32	80.33	78.35	76.35	74.35	72.33	70.29	66.18
112.85	109.07	11.50	5.46	85.01	83.99	82.97	81.94	80.91	79.88	77.81	75.72	73.62	71.51	69.38	65.09
111.13	120.13	12.00	5.17	84.77	83.69	82.62	81.54	80.47	79.38	77.21	75.02	72.82	70.61	68.38	63.87
109.33	132.50	12.50	4.89	84.49	83.36	82.23	81.10	79.96	78.83	76.54	74.24	71.92	69.59	67.25	62.51
107.42	146.41	13.00	4.60	84.18	82.99	81.79	80.60	79.40	78.20	75.79	73.36	70.91	68.46	65.98	60.98
105.39	162.18	13.50	4.31	83.82	82.56	81.30	80.03	78.76	77.49	74.93	72.36	69.77	67.17	64.54	59.25
103.23	180.20	14.00	4.02	83.42	82.08	80.73	79.38	78.03	76.68	73.96	71.22	68.46	65.69	62.90	57.27
100.92	200.99	14.50	3.74	82.95	81.52	80.08	78.64	77.19	75.74	72.83	69.90	66.96	63.99	61.01	54.98
98.43	225.25	15.00	3.45	82.41	80.86	79.31	77.76	76.21	74.65	71.52	68.36	65.20	62.01	58.80	52.31

**Table A4.2a. Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [60°F ≤ ΔT ≤ 110°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 60°F		ΔT = 70°F		ΔT = 80°F		ΔT = 90°F		ΔT = 100°F		ΔT = 110°F	
				η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing
138.02	0.00	0.00	12.07	88.79	96.29	88.58	95.11	88.37	93.68	88.16	91.94	87.94	89.81	87.73	87.73
137.26	2.20	0.50	11.78	88.76	96.21	88.55	95.02	88.34	93.56	88.12	91.78	87.91	89.61	87.69	87.69
136.49	4.50	1.00	11.50	88.74	96.14	88.52	94.91	88.30	93.43	88.08	91.62	87.86	89.41	87.64	87.64
135.69	6.93	1.50	11.21	88.71	96.05	88.49	94.81	88.27	93.29	88.04	91.44	87.82	89.19	87.60	87.60
134.87	9.48	2.00	10.92	88.69	95.97	88.46	94.70	88.23	93.15	88.00	91.26	87.77	88.96	87.55	87.55
134.03	12.18	2.50	10.63	88.66	95.88	88.42	94.58	88.19	93.00	87.96	91.07	87.73	88.72	87.49	87.49
133.16	15.02	3.00	10.35	88.63	95.78	88.39	94.46	88.15	92.84	87.91	90.87	87.68	88.46	87.44	87.44
132.27	18.02	3.50	10.06	88.59	95.68	88.35	94.32	88.11	92.67	87.86	90.66	87.62	88.20	87.38	87.38
131.35	21.20	4.00	9.77	88.56	95.57	88.31	94.18	88.06	92.49	87.81	90.43	87.56	87.91	87.31	87.31
130.4	24.57	4.50	9.48	88.52	95.46	88.27	94.04	88.01	92.31	87.76	90.19	87.50	87.61	87.25	87.25
129.43	28.16	5.00	9.20	88.48	95.34	88.22	93.88	87.96	92.11	87.70	89.94	87.44	87.44	87.18	87.18
128.42	31.97	5.50	8.91	88.44	95.21	88.18	93.71	87.91	91.89	87.64	89.67	87.37	87.37	87.10	87.10
127.37	36.04	6.00	8.62	88.40	95.07	88.12	93.54	87.85	91.66	87.57	89.38	87.30	87.30	87.02	87.02
126.3	40.39	6.50	8.33	88.35	94.92	88.07	93.35	87.79	91.42	87.50	89.07	87.22	87.22	86.94	86.94
125.18	45.05	7.00	8.05	88.30	94.76	88.01	93.14	87.72	91.16	87.43	88.74	87.14	87.14	86.84	86.84
124.02	50.05	7.50	7.76	88.25	94.59	87.95	92.92	87.65	90.88	87.35	88.38	87.05	87.05	86.74	86.74
122.82	55.45	8.00	7.47	88.19	94.41	87.88	92.69	87.57	90.58	87.26	88.00	86.95	86.95	86.64	86.64
121.57	61.27	8.50	7.18	88.13	94.21	87.81	92.43	87.49	90.25	87.17	87.59	86.85	86.85	86.52	86.52
120.27	67.57	9.00	6.90	88.06	94.00	87.73	92.16	87.40	89.90	87.06	87.14	86.73	86.73	86.40	86.40
118.91	74.43	9.50	6.61	87.99	93.77	87.64	91.86	87.30	89.52	86.95	86.95	86.61	86.61	86.26	86.26
117.5	81.91	10.00	6.32	87.91	93.52	87.55	91.53	87.19	89.10	86.83	86.83	86.47	86.47	86.12	86.12
116.02	90.10	10.50	6.04	87.82	93.24	87.45	91.17	87.07	88.64	86.70	86.70	86.33	86.33	85.95	85.95
114.47	99.11	11.00	5.75	87.72	92.93	87.33	90.78	86.94	88.14	86.56	86.56	86.17	86.17	85.78	85.78
112.85	109.07	11.50	5.46	87.61	92.60	87.21	90.34	86.80	87.58	86.39	86.39	85.99	85.99	85.58	85.58
111.13	120.13	12.00	5.17	87.49	92.22	87.07	89.86	86.64	86.96	86.22	86.22	85.79	85.79	85.36	85.36
109.33	132.50	12.50	4.89	87.36	91.80	86.91	89.32	86.46	86.46	86.02	86.02	85.57	85.57	85.12	85.12
107.42	146.41	13.00	4.60	87.21	91.33	86.74	88.71	86.26	86.26	85.79	85.79	85.32	85.32	84.84	84.84
105.39	162.18	13.50	4.31	87.04	90.80	86.54	88.02	86.04	86.04	85.54	85.54	85.03	85.03	84.53	84.53
103.23	180.20	14.00	4.02	86.85	90.19	86.31	87.23	85.78	85.78	85.25	85.25	84.71	84.71	84.17	84.17
100.92	200.99	14.50	3.74	86.62	89.49	86.05	86.32	85.48	85.48	84.91	84.91	84.34	84.34	83.76	83.76
98.43	225.25	15.00	3.45	86.36	88.67	85.75	85.75	85.13	85.13	84.52	84.52	83.90	83.90	83.28	83.28

**Table A4.2b. Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
138.02	0.00	0.00	12.07	87.42	86.89	86.35	85.82	85.28	84.75	83.67	82.58	81.48	80.38	79.27	77.02
137.26	2.20	0.50	11.78	87.37	86.83	86.28	85.74	85.20	84.65	83.55	82.44	81.32	80.20	79.07	76.78
136.49	4.50	1.00	11.50	87.31	86.76	86.21	85.66	85.10	84.54	83.42	82.29	81.16	80.01	78.86	76.52
135.69	6.93	1.50	11.21	87.26	86.70	86.14	85.57	85.00	84.43	83.29	82.14	80.98	79.81	78.64	76.26
134.87	9.48	2.00	10.92	87.20	86.63	86.06	85.48	84.90	84.32	83.15	81.98	80.79	79.60	78.40	75.97
134.03	12.18	2.50	10.63	87.14	86.56	85.97	85.38	84.79	84.20	83.01	81.81	80.60	79.38	78.16	75.68
133.16	15.02	3.00	10.35	87.08	86.48	85.88	85.28	84.68	84.07	82.85	81.63	80.39	79.15	77.90	75.37
132.27	18.02	3.50	10.06	87.01	86.40	85.79	85.17	84.55	83.93	82.69	81.44	80.18	78.90	77.62	75.04
131.35	21.20	4.00	9.77	86.94	86.31	85.69	85.06	84.43	83.79	82.52	81.24	79.94	78.64	77.33	74.69
130.4	24.57	4.50	9.48	86.86	86.22	85.58	84.94	84.29	83.64	82.33	81.02	79.70	78.37	77.03	74.31
129.43	28.16	5.00	9.20	86.78	86.13	85.47	84.81	84.14	83.48	82.14	80.79	79.44	78.07	76.70	73.92
128.42	31.97	5.50	8.91	86.70	86.02	85.35	84.67	83.99	83.31	81.93	80.55	79.16	77.76	76.35	73.50
127.37	36.04	6.00	8.62	86.61	85.91	85.22	84.52	83.82	83.12	81.71	80.29	78.87	77.43	75.98	73.05
126.3	40.39	6.50	8.33	86.51	85.80	85.08	84.37	83.65	82.93	81.48	80.02	78.55	77.07	75.58	72.57
125.18	45.05	7.00	8.05	86.40	85.67	84.94	84.20	83.46	82.72	81.22	79.72	78.21	76.69	75.16	72.06
124.02	50.05	7.50	7.76	86.29	85.54	84.78	84.02	83.26	82.49	80.95	79.41	77.85	76.28	74.70	71.51
122.82	55.45	8.00	7.47	86.17	85.39	84.61	83.82	83.04	82.25	80.66	79.06	77.46	75.84	74.21	70.92
121.57	61.27	8.50	7.18	86.04	85.23	84.43	83.61	82.80	81.99	80.35	78.70	77.04	75.36	73.68	70.28
120.27	67.57	9.00	6.90	85.90	85.06	84.23	83.39	82.55	81.70	80.00	78.30	76.58	74.85	73.10	69.58
118.91	74.43	9.50	6.61	85.74	84.88	84.01	83.14	82.27	81.39	79.63	77.86	76.08	74.29	72.48	68.83
117.5	81.91	10.00	6.32	85.58	84.68	83.78	82.87	81.96	81.05	79.23	77.39	75.54	73.67	71.80	68.00
116.02	90.10	10.50	6.04	85.39	84.46	83.52	82.58	81.63	80.69	78.78	76.87	74.94	73.00	71.05	67.10
114.47	99.11	11.00	5.75	85.19	84.21	83.23	82.25	81.27	80.28	78.29	76.30	74.29	72.26	70.23	66.11
112.85	109.07	11.50	5.46	84.97	83.95	82.92	81.89	80.86	79.83	77.75	75.67	73.56	71.45	69.32	65.02
111.13	120.13	12.00	5.17	84.72	83.65	82.57	81.50	80.41	79.33	77.15	74.97	72.76	70.54	68.31	63.80
109.33	132.50	12.50	4.89	84.44	83.31	82.18	81.05	79.91	78.77	76.48	74.18	71.86	69.53	67.18	62.44
107.42	146.41	13.00	4.60	84.13	82.94	81.75	80.55	79.35	78.15	75.73	73.30	70.85	68.39	65.91	60.91
105.39	162.18	13.50	4.31	83.77	82.51	81.25	79.98	78.71	77.44	74.88	72.30	69.71	67.10	64.47	59.17
103.23	180.20	14.00	4.02	83.37	82.03	80.68	79.33	77.98	76.62	73.90	71.16	68.40	65.62	62.83	57.19
100.92	200.99	14.50	3.74	82.90	81.47	80.03	78.58	77.14	75.69	72.77	69.84	66.89	63.92	60.93	54.90
98.43	225.25	15.00	3.45	82.36	80.81	79.26	77.71	76.15	74.59	71.46	68.30	65.13	61.94	58.72	52.23

**Table A4.3a. Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [50°F ≤ ΔT ≤ 100°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub> = 14.696 psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 50°F		ΔT = 60°F		ΔT = 70°F		ΔT = 80°F		ΔT = 90°F		ΔT = 100°F	
				η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing
138.02	0.00	0.00	12.07	88.95	96.45	88.74	95.28	88.53	93.85	88.32	92.10	88.11	89.98	87.90	87.90
137.26	2.20	0.50	11.78	88.93	96.38	88.72	95.19	88.51	93.73	88.29	91.95	88.08	89.78	87.86	87.86
136.49	4.50	1.00	11.50	88.91	96.31	88.70	95.09	88.48	93.60	88.26	91.79	88.04	89.58	87.82	87.82
135.69	6.93	1.50	11.21	88.89	96.23	88.67	94.99	88.45	93.47	88.22	91.62	88.00	89.37	87.78	87.78
134.87	9.48	2.00	10.92	88.87	96.15	88.64	94.88	88.41	93.33	88.19	91.45	87.96	89.14	87.73	87.73
134.03	12.18	2.50	10.63	88.85	96.06	88.61	94.77	88.38	93.19	88.15	91.26	87.91	88.91	87.68	87.68
133.16	15.02	3.00	10.35	88.82	95.97	88.58	94.65	88.34	93.03	88.11	91.06	87.87	88.66	87.63	87.63
132.27	18.02	3.50	10.06	88.79	95.88	88.55	94.52	88.31	92.87	88.06	90.85	87.82	88.39	87.58	87.58
131.35	21.20	4.00	9.77	88.76	95.78	88.52	94.39	88.27	92.70	88.02	90.63	87.77	88.12	87.52	87.52
130.4	24.57	4.50	9.48	88.73	95.67	88.48	94.25	88.22	92.52	87.97	90.40	87.71	87.82	87.46	87.46
129.43	28.16	5.00	9.20	88.70	95.55	88.44	94.10	88.18	92.32	87.92	90.15	87.66	87.66	87.39	87.39
128.42	31.97	5.50	8.91	88.67	95.43	88.40	93.94	88.13	92.12	87.86	89.89	87.59	87.59	87.33	87.33
127.37	36.04	6.00	8.62	88.63	95.30	88.36	93.77	88.08	91.90	87.80	89.61	87.53	87.53	87.25	87.25
126.3	40.39	6.50	8.33	88.59	95.16	88.31	93.58	88.03	91.66	87.74	89.31	87.46	87.46	87.17	87.17
125.18	45.05	7.00	8.05	88.55	95.01	88.26	93.39	87.97	91.41	87.68	88.98	87.38	87.38	87.09	87.09
124.02	50.05	7.50	7.76	88.51	94.85	88.21	93.18	87.90	91.14	87.60	88.64	87.30	87.30	87.00	87.00
122.82	55.45	8.00	7.47	88.46	94.68	88.15	92.95	87.84	90.85	87.53	88.26	87.22	87.22	86.90	86.90
121.57	61.27	8.50	7.18	88.40	94.49	88.08	92.71	87.76	90.53	87.44	87.86	87.12	87.12	86.80	86.80
120.27	67.57	9.00	6.90	88.35	94.29	88.02	92.44	87.68	90.19	87.35	87.43	87.02	87.02	86.69	86.69
118.91	74.43	9.50	6.61	88.29	94.07	87.94	92.16	87.60	89.82	87.25	87.25	86.91	86.91	86.56	86.56
117.5	81.91	10.00	6.32	88.22	93.83	87.86	91.84	87.50	89.41	87.15	87.15	86.79	86.79	86.43	86.43
116.02	90.10	10.50	6.04	88.15	93.57	87.77	91.50	87.40	88.97	87.03	87.03	86.66	86.66	86.28	86.28
114.47	99.11	11.00	5.75	88.07	93.28	87.68	91.12	87.29	88.48	86.90	86.90	86.51	86.51	86.12	86.12
112.85	109.07	11.50	5.46	87.98	92.96	87.57	90.71	87.16	87.94	86.76	86.76	86.35	86.35	85.94	85.94
111.13	120.13	12.00	5.17	87.88	92.60	87.45	90.24	87.02	87.34	86.60	86.60	86.17	86.17	85.74	85.74
109.33	132.50	12.50	4.89	87.77	92.21	87.32	89.72	86.87	86.87	86.42	86.42	85.97	85.97	85.52	85.52
107.42	146.41	13.00	4.60	87.64	91.76	87.17	89.14	86.69	86.69	86.22	86.22	85.75	85.75	85.27	85.27
105.39	162.18	13.50	4.31	87.50	91.26	87.00	88.48	86.50	86.50	85.99	85.99	85.49	85.49	84.99	84.99
103.23	180.20	14.00	4.02	87.34	90.68	86.80	87.72	86.27	86.27	85.73	85.73	85.20	85.20	84.66	84.66
100.92	200.99	14.50	3.74	87.15	90.01	86.58	86.85	86.01	86.01	85.44	85.44	84.86	84.86	84.29	84.29
98.43	225.25	15.00	3.45	86.93	89.24	86.32	86.32	85.70	85.70	85.09	85.09	84.47	84.47	83.85	83.85



**Table A4.3b. Nat Gas; [HHV = 980 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
138.02	0.00	0.00	12.07	87.37	86.84	86.31	85.77	85.24	84.70	83.62	82.53	81.43	80.32	79.21	76.96
137.26	2.20	0.50	11.78	87.32	86.78	86.24	85.69	85.15	84.60	83.50	82.39	81.27	80.14	79.01	76.72
136.49	4.50	1.00	11.50	87.27	86.72	86.16	85.61	85.05	84.49	83.37	82.24	81.10	79.96	78.80	76.46
135.69	6.93	1.50	11.21	87.21	86.65	86.09	85.52	84.95	84.39	83.24	82.09	80.93	79.76	78.58	76.19
134.87	9.48	2.00	10.92	87.16	86.58	86.01	85.43	84.85	84.27	83.10	81.93	80.74	79.55	78.34	75.91
134.03	12.18	2.50	10.63	87.10	86.51	85.92	85.33	84.74	84.15	82.96	81.75	80.54	79.33	78.10	75.62
133.16	15.02	3.00	10.35	87.03	86.43	85.83	85.23	84.63	84.02	82.80	81.57	80.34	79.09	77.84	75.30
132.27	18.02	3.50	10.06	86.97	86.35	85.74	85.12	84.51	83.89	82.64	81.38	80.12	78.85	77.57	74.97
131.35	21.20	4.00	9.77	86.89	86.27	85.64	85.01	84.38	83.74	82.47	81.18	79.89	78.59	77.28	74.62
130.4	24.57	4.50	9.48	86.82	86.18	85.53	84.89	84.24	83.59	82.28	80.97	79.64	78.31	76.97	74.25
129.43	28.16	5.00	9.20	86.74	86.08	85.42	84.76	84.09	83.43	82.09	80.74	79.38	78.02	76.64	73.86
128.42	31.97	5.50	8.91	86.65	85.98	85.30	84.62	83.94	83.26	81.88	80.50	79.11	77.70	76.29	73.44
127.37	36.04	6.00	8.62	86.56	85.87	85.17	84.47	83.77	83.07	81.66	80.24	78.81	77.37	75.92	72.99
126.3	40.39	6.50	8.33	86.46	85.75	85.03	84.32	83.60	82.88	81.43	79.97	78.49	77.01	75.52	72.51
125.18	45.05	7.00	8.05	86.36	85.62	84.89	84.15	83.41	82.67	81.17	79.67	78.16	76.63	75.10	72.00
124.02	50.05	7.50	7.76	86.25	85.49	84.73	83.97	83.21	82.44	80.90	79.35	77.79	76.22	74.64	71.44
122.82	55.45	8.00	7.47	86.13	85.34	84.56	83.78	82.99	82.20	80.61	79.01	77.40	75.78	74.15	70.85
121.57	61.27	8.50	7.18	85.99	85.19	84.38	83.57	82.75	81.93	80.29	78.64	76.98	75.30	73.62	70.21
120.27	67.57	9.00	6.90	85.85	85.02	84.18	83.34	82.50	81.65	79.95	78.24	76.52	74.79	73.04	69.51
118.91	74.43	9.50	6.61	85.70	84.83	83.96	83.09	82.22	81.34	79.58	77.81	76.02	74.22	72.42	68.76
117.5	81.91	10.00	6.32	85.53	84.63	83.73	82.82	81.91	81.00	79.17	77.33	75.48	73.61	71.73	67.94
116.02	90.10	10.50	6.04	85.35	84.41	83.47	82.53	81.58	80.63	78.73	76.81	74.88	72.94	70.98	67.03
114.47	99.11	11.00	5.75	85.14	84.17	83.19	82.20	81.22	80.23	78.24	76.24	74.23	72.20	70.16	66.04
112.85	109.07	11.50	5.46	84.92	83.90	82.87	81.84	80.81	79.78	77.70	75.61	73.50	71.39	69.25	64.94
111.13	120.13	12.00	5.17	84.67	83.60	82.52	81.45	80.36	79.28	77.10	74.91	72.70	70.48	68.24	63.73
109.33	132.50	12.50	4.89	84.39	83.27	82.13	81.00	79.86	78.72	76.43	74.12	71.80	69.47	67.11	62.36
107.42	146.41	13.00	4.60	84.08	82.89	81.70	80.50	79.30	78.09	75.67	73.24	70.79	68.33	65.84	60.83
105.39	162.18	13.50	4.31	83.73	82.47	81.20	79.93	78.66	77.38	74.82	72.24	69.65	67.03	64.40	59.09
103.23	180.20	14.00	4.02	83.32	81.98	80.63	79.28	77.93	76.57	73.84	71.10	68.34	65.56	62.76	57.11
100.92	200.99	14.50	3.74	82.86	81.42	79.98	78.53	77.08	75.63	72.71	69.78	66.83	63.85	60.86	54.82
98.43	225.25	15.00	3.45	82.31	80.76	79.21	77.66	76.10	74.54	71.40	68.24	65.06	61.86	58.65	52.15

**Table A4.4a. Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [70°F ≤ ΔT ≤ 120°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 70°F		ΔT = 80°F		ΔT = 90°F		ΔT = 100°F		ΔT = 110°F		ΔT = 120°F	
				η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing
138.02	0.00	0.00	12.07	89.17	96.31	88.97	95.19	88.77	93.83	88.57	92.17	88.37	90.15	88.17	88.17
137.26	2.20	0.50	11.78	89.15	96.24	88.94	95.10	88.74	93.71	88.54	92.02	88.33	89.95	88.13	88.13
136.49	4.50	1.00	11.50	89.12	96.16	88.91	95.00	88.70	93.58	88.50	91.86	88.29	89.75	88.08	88.08
135.69	6.93	1.50	11.21	89.09	96.08	88.88	94.89	88.67	93.45	88.45	91.69	88.24	89.54	88.03	88.03
134.87	9.48	2.00	10.92	89.06	95.99	88.84	94.78	88.63	93.31	88.41	91.51	88.19	89.32	87.98	87.98
134.03	12.18	2.50	10.63	89.03	95.90	88.81	94.66	88.59	93.16	88.36	91.33	88.14	89.09	87.92	87.92
133.16	15.02	3.00	10.35	88.99	95.80	88.77	94.54	88.54	93.00	88.32	91.13	88.09	88.84	87.86	87.86
132.27	18.02	3.50	10.06	88.96	95.70	88.73	94.41	88.50	92.84	88.26	90.92	88.03	88.58	87.80	87.80
131.35	21.20	4.00	9.77	88.92	95.59	88.68	94.27	88.45	92.66	88.21	90.70	87.97	88.30	87.74	87.74
130.4	24.57	4.50	9.48	88.88	95.48	88.64	94.13	88.40	92.48	88.15	90.47	87.91	88.01	87.67	87.67
129.43	28.16	5.00	9.20	88.84	95.36	88.59	93.97	88.34	92.28	88.09	90.22	87.84	87.84	87.59	87.59
128.42	31.97	5.50	8.91	88.79	95.23	88.54	93.81	88.28	92.07	88.03	89.95	87.77	87.77	87.52	87.52
127.37	36.04	6.00	8.62	88.74	95.09	88.48	93.63	88.22	91.85	87.96	89.67	87.69	87.69	87.43	87.43
126.3	40.39	6.50	8.33	88.69	94.94	88.42	93.44	88.15	91.61	87.88	89.37	87.61	87.61	87.34	87.34
125.18	45.05	7.00	8.05	88.64	94.78	88.36	93.24	88.08	91.35	87.80	89.05	87.53	87.53	87.25	87.25
124.02	50.05	7.50	7.76	88.58	94.61	88.29	93.02	88.00	91.08	87.72	88.70	87.43	87.43	87.14	87.14
122.82	55.45	8.00	7.47	88.51	94.43	88.22	92.79	87.92	90.78	87.63	88.33	87.33	87.33	87.03	87.03
121.57	61.27	8.50	7.18	88.44	94.23	88.14	92.54	87.83	90.46	87.53	87.93	87.22	87.22	86.91	86.91
120.27	67.57	9.00	6.90	88.37	94.02	88.05	92.26	87.73	90.12	87.42	87.49	87.10	87.10	86.79	86.79
118.91	74.43	9.50	6.61	88.28	93.79	87.96	91.97	87.63	89.74	87.30	87.30	86.97	86.97	86.64	86.64
117.5	81.91	10.00	6.32	88.20	93.53	87.85	91.64	87.51	89.33	87.17	87.17	86.83	86.83	86.49	86.49
116.02	90.10	10.50	6.04	88.10	93.26	87.74	91.29	87.39	88.88	87.03	87.03	86.68	86.68	86.32	86.32
114.47	99.11	11.00	5.75	87.99	92.95	87.62	90.90	87.25	88.39	86.88	86.88	86.51	86.51	86.14	86.14
112.85	109.07	11.50	5.46	87.87	92.61	87.48	90.47	87.10	87.84	86.71	86.71	86.32	86.32	85.93	85.93
111.13	120.13	12.00	5.17	87.74	92.24	87.33	89.99	86.93	87.23	86.52	86.52	86.11	86.11	85.71	85.71
109.33	132.50	12.50	4.89	87.59	91.82	87.16	89.45	86.74	86.74	86.31	86.31	85.88	85.88	85.45	85.45
107.42	146.41	13.00	4.60	87.42	91.35	86.97	88.85	86.52	86.52	86.07	86.07	85.62	85.62	85.17	85.17
105.39	162.18	13.50	4.31	87.24	90.81	86.76	88.17	86.28	86.28	85.80	85.80	85.32	85.32	84.85	84.85
103.23	180.20	14.00	4.02	87.02	90.20	86.51	87.39	86.00	86.00	85.50	85.50	84.99	84.99	84.48	84.48
100.92	200.99	14.50	3.74	86.77	89.50	86.23	86.49	85.68	85.68	85.14	85.14	84.60	84.60	84.05	84.05
98.43	225.25	15.00	3.45	86.48	88.67	85.90	85.90	85.31	85.31	84.73	84.73	84.14	84.14	83.55	83.55

**Table A4.4b. Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub> = 14.696 psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
138.02	0.00	0.00	12.07	88.07	87.57	87.06	86.55	86.04	85.53	84.51	83.47	82.43	81.38	80.33	78.19
137.26	2.20	0.50	11.78	88.02	87.51	86.99	86.48	85.96	85.44	84.39	83.34	82.28	81.21	80.14	77.96
136.49	4.50	1.00	11.50	87.97	87.45	86.93	86.40	85.87	85.34	84.28	83.20	82.12	81.03	79.94	77.72
135.69	6.93	1.50	11.21	87.92	87.39	86.85	86.32	85.78	85.24	84.15	83.06	81.95	80.84	79.73	77.47
134.87	9.48	2.00	10.92	87.87	87.32	86.78	86.23	85.68	85.13	84.02	82.90	81.78	80.65	79.51	77.20
134.03	12.18	2.50	10.63	87.81	87.25	86.70	86.14	85.57	85.01	83.88	82.74	81.59	80.44	79.27	76.92
133.16	15.02	3.00	10.35	87.75	87.18	86.61	86.04	85.47	84.89	83.73	82.57	81.40	80.22	79.03	76.62
132.27	18.02	3.50	10.06	87.69	87.10	86.52	85.94	85.35	84.76	83.58	82.39	81.19	79.98	78.76	76.31
131.35	21.20	4.00	9.77	87.62	87.02	86.43	85.83	85.23	84.62	83.41	82.20	80.97	79.73	78.49	75.97
130.4	24.57	4.50	9.48	87.55	86.94	86.32	85.71	85.10	84.48	83.24	81.99	80.74	79.47	78.20	75.62
129.43	28.16	5.00	9.20	87.47	86.84	86.22	85.59	84.96	84.33	83.06	81.78	80.49	79.19	77.89	75.25
128.42	31.97	5.50	8.91	87.39	86.75	86.10	85.46	84.81	84.16	82.86	81.55	80.23	78.90	77.56	74.85
127.37	36.04	6.00	8.62	87.30	86.64	85.98	85.32	84.65	83.99	82.65	81.30	79.94	78.58	77.20	74.42
126.3	40.39	6.50	8.33	87.21	86.53	85.85	85.17	84.49	83.80	82.43	81.04	79.64	78.24	76.83	73.97
125.18	45.05	7.00	8.05	87.11	86.41	85.71	85.01	84.31	83.60	82.19	80.76	79.32	77.88	76.42	73.48
124.02	50.05	7.50	7.76	87.00	86.28	85.56	84.84	84.11	83.39	81.93	80.46	78.98	77.49	75.99	72.95
122.82	55.45	8.00	7.47	86.89	86.14	85.40	84.65	83.91	83.16	81.65	80.13	78.61	77.07	75.52	72.39
121.57	61.27	8.50	7.18	86.76	85.99	85.23	84.46	83.68	82.91	81.35	79.78	78.20	76.61	75.01	71.78
120.27	67.57	9.00	6.90	86.63	85.83	85.04	84.24	83.44	82.64	81.02	79.40	77.77	76.12	74.47	71.12
118.91	74.43	9.50	6.61	86.48	85.66	84.83	84.00	83.18	82.34	80.67	78.99	77.29	75.59	73.87	70.40
117.5	81.91	10.00	6.32	86.32	85.47	84.61	83.75	82.89	82.02	80.29	78.54	76.78	75.01	73.22	69.62
116.02	90.10	10.50	6.04	86.15	85.26	84.36	83.47	82.57	81.67	79.86	78.04	76.21	74.37	72.51	68.76
114.47	99.11	11.00	5.75	85.95	85.02	84.09	83.16	82.22	81.28	79.40	77.50	75.59	73.67	71.73	67.82
112.85	109.07	11.50	5.46	85.74	84.77	83.80	82.82	81.84	80.86	78.89	76.90	74.90	72.89	70.87	66.78
111.13	120.13	12.00	5.17	85.50	84.49	83.46	82.44	81.41	80.38	78.32	76.23	74.14	72.03	69.91	65.62
109.33	132.50	12.50	4.89	85.24	84.17	83.09	82.02	80.94	79.85	77.68	75.49	73.29	71.07	68.84	64.33
107.42	146.41	13.00	4.60	84.94	83.81	82.68	81.54	80.40	79.26	76.96	74.65	72.33	69.99	67.63	62.87
105.39	162.18	13.50	4.31	84.61	83.41	82.21	81.00	79.79	78.58	76.15	73.70	71.24	68.76	66.26	61.22
103.23	180.20	14.00	4.02	84.22	82.95	81.67	80.38	79.10	77.81	75.22	72.61	69.99	67.36	64.70	59.34
100.92	200.99	14.50	3.74	83.78	82.41	81.04	79.67	78.30	76.92	74.15	71.36	68.56	65.74	62.90	57.16
98.43	225.25	15.00	3.45	83.26	81.79	80.32	78.84	77.36	75.88	72.90	69.90	66.88	63.85	60.79	54.63

**Table A4.5a. Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [60°F ≤ ΔT ≤ 110°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 60°F		ΔT = 70°F		ΔT = 80°F		ΔT = 90°F		ΔT = 100°F		ΔT = 110°F	
				η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing
138.02	0.00	0.00	12.07	89.33	96.47	89.13	95.35	88.93	93.99	88.73	92.33	88.53	90.30	88.33	88.33
137.26	2.20	0.50	11.78	89.31	96.40	89.11	95.26	88.90	93.87	88.70	92.18	88.49	90.12	88.29	88.29
136.49	4.50	1.00	11.50	89.29	96.32	89.08	95.16	88.87	93.75	88.66	92.02	88.45	89.92	88.24	88.24
135.69	6.93	1.50	11.21	89.26	96.25	89.05	95.06	88.84	93.62	88.62	91.86	88.41	89.71	88.20	88.20
134.87	9.48	2.00	10.92	89.23	96.16	89.02	94.95	88.80	93.48	88.58	91.69	88.37	89.50	88.15	88.15
134.03	12.18	2.50	10.63	89.21	96.08	88.99	94.84	88.77	93.34	88.54	91.50	88.32	89.27	88.10	88.10
133.16	15.02	3.00	10.35	89.18	95.98	88.95	94.72	88.73	93.19	88.50	91.31	88.27	89.02	88.05	88.05
132.27	18.02	3.50	10.06	89.15	95.89	88.92	94.60	88.69	93.03	88.45	91.11	88.22	88.77	87.99	87.99
131.35	21.20	4.00	9.77	89.11	95.79	88.88	94.47	88.64	92.86	88.40	90.89	88.17	88.50	87.93	87.93
130.4	24.57	4.50	9.48	89.08	95.68	88.84	94.33	88.60	92.68	88.35	90.67	88.11	88.21	87.87	87.87
129.43	28.16	5.00	9.20	89.04	95.56	88.80	94.18	88.55	92.49	88.30	90.42	88.05	88.05	87.80	87.80
128.42	31.97	5.50	8.91	89.00	95.44	88.75	94.02	88.49	92.29	88.24	90.17	87.98	87.98	87.73	87.73
127.37	36.04	6.00	8.62	88.96	95.31	88.70	93.85	88.44	92.07	88.18	89.89	87.91	87.91	87.65	87.65
126.3	40.39	6.50	8.33	88.92	95.17	88.65	93.67	88.38	91.84	88.11	89.60	87.84	87.84	87.57	87.57
125.18	45.05	7.00	8.05	88.87	95.02	88.59	93.47	88.32	91.59	88.04	89.28	87.76	87.76	87.48	87.48
124.02	50.05	7.50	7.76	88.82	94.86	88.53	93.27	88.25	91.32	87.96	88.95	87.67	87.67	87.39	87.39
122.82	55.45	8.00	7.47	88.76	94.68	88.47	93.04	88.17	91.04	87.88	88.58	87.58	87.58	87.29	87.29
121.57	61.27	8.50	7.18	88.70	94.50	88.40	92.80	88.09	90.73	87.79	88.19	87.48	87.48	87.18	87.18
120.27	67.57	9.00	6.90	88.64	94.29	88.32	92.54	88.01	90.39	87.69	87.76	87.38	87.38	87.06	87.06
118.91	74.43	9.50	6.61	88.57	94.07	88.24	92.25	87.91	90.03	87.59	87.59	87.26	87.26	86.93	86.93
117.5	81.91	10.00	6.32	88.49	93.83	88.15	91.94	87.81	89.63	87.47	87.47	87.13	87.13	86.79	86.79
116.02	90.10	10.50	6.04	88.41	93.57	88.05	91.60	87.70	89.19	87.35	87.35	86.99	86.99	86.64	86.64
114.47	99.11	11.00	5.75	88.32	93.28	87.95	91.23	87.58	88.71	87.21	87.21	86.84	86.84	86.47	86.47
112.85	109.07	11.50	5.46	88.21	92.96	87.83	90.81	87.44	88.18	87.05	87.05	86.67	86.67	86.28	86.28
111.13	120.13	12.00	5.17	88.10	92.60	87.70	90.35	87.29	87.59	86.88	86.88	86.48	86.48	86.07	86.07
109.33	132.50	12.50	4.89	87.97	92.20	87.55	89.84	87.12	87.12	86.69	86.69	86.27	86.27	85.84	85.84
107.42	146.41	13.00	4.60	87.83	91.75	87.38	89.26	86.93	86.93	86.48	86.48	86.03	86.03	85.58	85.58
105.39	162.18	13.50	4.31	87.67	91.25	87.19	88.60	86.72	86.72	86.24	86.24	85.76	85.76	85.28	85.28
103.23	180.20	14.00	4.02	87.49	90.67	86.98	87.85	86.47	86.47	85.96	85.96	85.45	85.45	84.94	84.94
100.92	200.99	14.50	3.74	87.27	90.00	86.73	86.99	86.19	86.19	85.64	85.64	85.10	85.10	84.55	84.55
98.43	225.25	15.00	3.45	87.02	89.22	86.44	86.44	85.85	85.85	85.27	85.27	84.68	84.68	84.10	84.10

**Table A4.5b. Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
138.02	0.00	0.00	12.07	88.03	87.52	87.02	86.51	86.00	85.49	84.46	83.42	82.38	81.33	80.27	78.13
137.26	2.20	0.50	11.78	87.98	87.47	86.95	86.43	85.91	85.39	84.35	83.29	82.23	81.16	80.08	77.90
136.49	4.50	1.00	11.50	87.93	87.41	86.88	86.35	85.82	85.29	84.23	83.15	82.07	80.98	79.88	77.66
135.69	6.93	1.50	11.21	87.88	87.34	86.81	86.27	85.73	85.19	84.10	83.01	81.90	80.79	79.67	77.41
134.87	9.48	2.00	10.92	87.82	87.28	86.73	86.18	85.63	85.08	83.97	82.85	81.73	80.59	79.45	77.14
134.03	12.18	2.50	10.63	87.77	87.21	86.65	86.09	85.53	84.96	83.83	82.69	81.54	80.38	79.22	76.86
133.16	15.02	3.00	10.35	87.71	87.14	86.57	85.99	85.42	84.84	83.68	82.52	81.34	80.16	78.97	76.56
132.27	18.02	3.50	10.06	87.64	87.06	86.48	85.89	85.30	84.71	83.53	82.34	81.14	79.93	78.71	76.25
131.35	21.20	4.00	9.77	87.57	86.98	86.38	85.78	85.18	84.58	83.37	82.15	80.92	79.68	78.43	75.91
130.4	24.57	4.50	9.48	87.50	86.89	86.28	85.67	85.05	84.43	83.19	81.94	80.68	79.42	78.14	75.56
129.43	28.16	5.00	9.20	87.43	86.80	86.17	85.54	84.91	84.28	83.01	81.73	80.44	79.14	77.83	75.19
128.42	31.97	5.50	8.91	87.34	86.70	86.06	85.41	84.77	84.12	82.81	81.50	80.17	78.84	77.50	74.79
127.37	36.04	6.00	8.62	87.26	86.60	85.94	85.27	84.61	83.94	82.60	81.25	79.89	78.52	77.15	74.36
126.3	40.39	6.50	8.33	87.16	86.49	85.81	85.12	84.44	83.75	82.38	80.99	79.59	78.18	76.77	73.90
125.18	45.05	7.00	8.05	87.06	86.37	85.67	84.96	84.26	83.55	82.14	80.71	79.27	77.82	76.36	73.42
124.02	50.05	7.50	7.76	86.96	86.24	85.52	84.79	84.07	83.34	81.88	80.41	78.92	77.43	75.93	72.89
122.82	55.45	8.00	7.47	86.84	86.10	85.36	84.61	83.86	83.11	81.60	80.08	78.55	77.01	75.46	72.33
121.57	61.27	8.50	7.18	86.72	85.95	85.18	84.41	83.64	82.86	81.30	79.73	78.15	76.56	74.96	71.72
120.27	67.57	9.00	6.90	86.58	85.79	84.99	84.19	83.39	82.59	80.97	79.35	77.71	76.07	74.41	71.06
118.91	74.43	9.50	6.61	86.44	85.61	84.79	83.96	83.13	82.29	80.62	78.94	77.24	75.53	73.81	70.34
117.5	81.91	10.00	6.32	86.28	85.42	84.56	83.70	82.84	81.97	80.23	78.48	76.72	74.95	73.16	69.56
116.02	90.10	10.50	6.04	86.10	85.21	84.32	83.42	82.52	81.62	79.81	77.99	76.16	74.31	72.45	68.70
114.47	99.11	11.00	5.75	85.91	84.98	84.05	83.11	82.18	81.24	79.35	77.45	75.53	73.61	71.67	67.76
112.85	109.07	11.50	5.46	85.70	84.72	83.75	82.77	81.79	80.81	78.83	76.85	74.85	72.83	70.81	66.71
111.13	120.13	12.00	5.17	85.46	84.44	83.42	82.39	81.36	80.33	78.26	76.18	74.08	71.97	69.85	65.55
109.33	132.50	12.50	4.89	85.20	84.12	83.05	81.97	80.89	79.80	77.63	75.43	73.23	71.01	68.77	64.26
107.42	146.41	13.00	4.60	84.90	83.77	82.63	81.49	80.35	79.21	76.91	74.59	72.27	69.92	67.57	62.80
105.39	162.18	13.50	4.31	84.56	83.36	82.16	80.95	79.74	78.53	76.09	73.64	71.18	68.70	66.20	61.15
103.23	180.20	14.00	4.02	84.18	82.90	81.62	80.34	79.05	77.76	75.17	72.56	69.93	67.29	64.63	59.26
100.92	200.99	14.50	3.74	83.73	82.37	81.00	79.62	78.25	76.87	74.09	71.30	68.50	65.67	62.83	57.09
98.43	225.25	15.00	3.45	83.21	81.74	80.27	78.79	77.31	75.83	72.84	69.84	66.82	63.78	60.72	54.55

**Table A4.6a. Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [50°F ≤ ΔT ≤ 100°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 50°F		ΔT = 60°F		ΔT = 70°F		ΔT = 80°F		ΔT = 90°F		ΔT = 100°F	
				η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing
138.02	0.00	0.00	12.07	89.49	96.63	89.29	95.51	89.09	94.15	88.89	92.49	88.69	90.46	88.49	88.49
137.26	2.20	0.50	11.78	89.47	96.56	89.27	95.42	89.06	94.03	88.86	92.34	88.65	90.28	88.45	88.45
136.49	4.50	1.00	11.50	89.45	96.49	89.24	95.33	89.04	93.91	88.83	92.19	88.62	90.09	88.41	88.41
135.69	6.93	1.50	11.21	89.43	96.42	89.22	95.23	89.01	93.79	88.79	92.03	88.58	89.88	88.37	88.37
134.87	9.48	2.00	10.92	89.41	96.34	89.19	95.13	88.98	93.66	88.76	91.86	88.54	89.67	88.32	88.32
134.03	12.18	2.50	10.63	89.39	96.26	89.17	95.02	88.94	93.52	88.72	91.68	88.50	89.45	88.28	88.28
133.16	15.02	3.00	10.35	89.36	96.17	89.14	94.91	88.91	93.37	88.68	91.50	88.46	89.21	88.23	88.23
132.27	18.02	3.50	10.06	89.34	96.08	89.11	94.79	88.87	93.22	88.64	91.30	88.41	88.96	88.18	88.18
131.35	21.20	4.00	9.77	89.31	95.98	89.07	94.66	88.84	93.05	88.60	91.09	88.36	88.69	88.12	88.12
130.4	24.57	4.50	9.48	89.28	95.88	89.04	94.53	88.80	92.88	88.55	90.87	88.31	88.41	88.07	88.07
129.43	28.16	5.00	9.20	89.25	95.77	89.00	94.38	88.75	92.69	88.50	90.63	88.26	88.26	88.01	88.01
128.42	31.97	5.50	8.91	89.22	95.65	88.96	94.23	88.71	92.50	88.45	90.38	88.20	88.20	87.94	87.94
127.37	36.04	6.00	8.62	89.18	95.53	88.92	94.07	88.66	92.29	88.40	90.11	88.13	88.13	87.87	87.87
126.3	40.39	6.50	8.33	89.15	95.39	88.88	93.90	88.61	92.06	88.34	89.83	88.07	88.07	87.80	87.80
125.18	45.05	7.00	8.05	89.11	95.25	88.83	93.71	88.55	91.82	88.27	89.52	88.00	88.00	87.72	87.72
124.02	50.05	7.50	7.76	89.06	95.10	88.78	93.51	88.49	91.57	88.20	89.19	87.92	87.92	87.63	87.63
122.82	55.45	8.00	7.47	89.02	94.94	88.72	93.30	88.43	91.29	88.13	88.83	87.84	87.84	87.54	87.54
121.57	61.27	8.50	7.18	88.97	94.76	88.66	93.06	88.36	90.99	88.05	88.45	87.75	87.75	87.44	87.44
120.27	67.57	9.00	6.90	88.91	94.57	88.60	92.81	88.28	90.66	87.97	88.04	87.65	87.65	87.33	87.33
118.91	74.43	9.50	6.61	88.85	94.36	88.53	92.54	88.20	90.31	87.87	87.87	87.54	87.54	87.22	87.22
117.5	81.91	10.00	6.32	88.79	94.13	88.45	92.24	88.11	89.93	87.77	87.77	87.43	87.43	87.09	87.09
116.02	90.10	10.50	6.04	88.72	93.88	88.37	91.91	88.01	89.50	87.66	87.66	87.30	87.30	86.95	86.95
114.47	99.11	11.00	5.75	88.64	93.60	88.27	91.55	87.90	89.04	87.53	87.53	87.16	87.16	86.79	86.79
112.85	109.07	11.50	5.46	88.56	93.30	88.17	91.16	87.79	88.53	87.40	87.40	87.01	87.01	86.62	86.62
111.13	120.13	12.00	5.17	88.46	92.96	88.06	90.71	87.65	87.96	87.25	87.25	86.84	86.84	86.43	86.43
109.33	132.50	12.50	4.89	88.36	92.59	87.93	90.22	87.51	87.51	87.08	87.08	86.65	86.65	86.22	86.22
107.42	146.41	13.00	4.60	88.24	92.16	87.79	89.67	87.34	87.34	86.89	86.89	86.44	86.44	85.99	85.99
105.39	162.18	13.50	4.31	88.11	91.68	87.63	89.04	87.15	87.15	86.67	86.67	86.19	86.19	85.72	85.72
103.23	180.20	14.00	4.02	87.95	91.13	87.44	88.32	86.94	86.94	86.43	86.43	85.92	85.92	85.41	85.41
100.92	200.99	14.50	3.74	87.77	90.50	87.23	87.49	86.69	86.69	86.14	86.14	85.60	85.60	85.05	85.05
98.43	225.25	15.00	3.45	87.57	89.76	86.98	86.98	86.40	86.40	85.81	85.81	85.22	85.22	84.64	84.64

**Table A4.6b. Nat Gas; [HHV = 1030 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
138.02	0.00	0.00	12.07	87.98	87.48	86.97	86.46	85.95	85.44	84.41	83.37	82.33	81.28	80.22	78.08
137.26	2.20	0.50	11.78	87.94	87.42	86.91	86.39	85.87	85.35	84.30	83.24	82.18	81.11	80.03	77.85
136.49	4.50	1.00	11.50	87.89	87.36	86.84	86.31	85.78	85.25	84.18	83.10	82.02	80.93	79.83	77.60
135.69	6.93	1.50	11.21	87.84	87.30	86.76	86.22	85.68	85.14	84.05	82.96	81.85	80.74	79.62	77.35
134.87	9.48	2.00	10.92	87.78	87.23	86.69	86.14	85.59	85.03	83.92	82.80	81.67	80.54	79.40	77.08
134.03	12.18	2.50	10.63	87.72	87.17	86.61	86.05	85.48	84.92	83.78	82.64	81.49	80.33	79.16	76.80
133.16	15.02	3.00	10.35	87.66	87.09	86.52	85.95	85.37	84.80	83.64	82.47	81.29	80.11	78.91	76.50
132.27	18.02	3.50	10.06	87.60	87.02	86.43	85.84	85.26	84.67	83.48	82.29	81.08	79.87	78.65	76.19
131.35	21.20	4.00	9.77	87.53	86.93	86.34	85.74	85.13	84.53	83.32	82.10	80.86	79.63	78.38	75.85
130.4	24.57	4.50	9.48	87.46	86.85	86.23	85.62	85.00	84.39	83.14	81.89	80.63	79.36	78.08	75.50
129.43	28.16	5.00	9.20	87.38	86.76	86.13	85.50	84.87	84.23	82.96	81.68	80.38	79.08	77.77	75.13
128.42	31.97	5.50	8.91	87.30	86.66	86.01	85.37	84.72	84.07	82.76	81.45	80.12	78.79	77.44	74.73
127.37	36.04	6.00	8.62	87.21	86.55	85.89	85.23	84.56	83.89	82.55	81.20	79.84	78.47	77.09	74.30
126.3	40.39	6.50	8.33	87.12	86.44	85.76	85.08	84.39	83.71	82.33	80.94	79.54	78.13	76.71	73.84
125.18	45.05	7.00	8.05	87.02	86.32	85.62	84.92	84.21	83.51	82.09	80.66	79.22	77.77	76.31	73.35
124.02	50.05	7.50	7.76	86.91	86.19	85.47	84.75	84.02	83.29	81.83	80.35	78.87	77.38	75.87	72.83
122.82	55.45	8.00	7.47	86.80	86.05	85.31	84.56	83.81	83.06	81.55	80.03	78.50	76.96	75.40	72.26
121.57	61.27	8.50	7.18	86.67	85.91	85.14	84.36	83.59	82.81	81.25	79.68	78.09	76.50	74.90	71.65
120.27	67.57	9.00	6.90	86.54	85.74	84.95	84.15	83.34	82.54	80.92	79.30	77.66	76.01	74.35	70.99
118.91	74.43	9.50	6.61	86.39	85.57	84.74	83.91	83.08	82.25	80.57	78.88	77.18	75.47	73.75	70.28
117.5	81.91	10.00	6.32	86.23	85.38	84.52	83.66	82.79	81.92	80.18	78.43	76.67	74.89	73.10	69.49
116.02	90.10	10.50	6.04	86.06	85.17	84.27	83.37	82.48	81.57	79.76	77.94	76.10	74.25	72.39	68.63
114.47	99.11	11.00	5.75	85.87	84.93	84.00	83.07	82.13	81.19	79.30	77.39	75.48	73.55	71.61	67.69
112.85	109.07	11.50	5.46	85.65	84.68	83.70	82.72	81.74	80.76	78.78	76.79	74.79	72.77	70.74	66.64
111.13	120.13	12.00	5.17	85.42	84.39	83.37	82.35	81.32	80.28	78.21	76.12	74.02	71.91	69.78	65.48
109.33	132.50	12.50	4.89	85.15	84.08	83.00	81.92	80.84	79.75	77.57	75.38	73.17	70.95	68.71	64.19
107.42	146.41	13.00	4.60	84.85	83.72	82.58	81.44	80.30	79.16	76.85	74.54	72.21	69.86	67.50	62.73
105.39	162.18	13.50	4.31	84.52	83.32	82.11	80.90	79.69	78.48	76.04	73.59	71.12	68.63	66.13	61.08
103.23	180.20	14.00	4.02	84.13	82.85	81.57	80.29	79.00	77.71	75.11	72.50	69.87	67.23	64.57	59.19
100.92	200.99	14.50	3.74	83.69	82.32	80.95	79.57	78.20	76.81	74.04	71.24	68.43	65.61	62.76	57.01
98.43	225.25	15.00	3.45	83.17	81.70	80.22	78.74	77.26	75.77	72.79	69.78	66.76	63.71	60.65	54.47

**Table A4.7a. Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [70°F ≤ ΔT ≤ 120°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 70°F		ΔT = 80°F		ΔT = 90°F		ΔT = 100°F		ΔT = 110°F		ΔT = 120°F	
				η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing
138.02	0.00	0.00	12.07	89.68	96.48	89.48	95.41	89.29	94.11	89.10	92.53	88.91	90.60	88.72	88.72
137.26	2.20	0.50	11.78	89.65	96.41	89.46	95.32	89.26	94.00	89.07	92.39	88.87	90.42	88.68	88.68
136.49	4.50	1.00	11.50	89.62	96.34	89.43	95.23	89.23	93.88	89.03	92.23	88.83	90.23	88.63	88.63
135.69	6.93	1.50	11.21	89.60	96.26	89.39	95.13	89.19	93.75	88.99	92.07	88.79	90.03	88.58	88.58
134.87	9.48	2.00	10.92	89.57	96.17	89.36	95.02	89.15	93.62	88.95	91.90	88.74	89.82	88.53	88.53
134.03	12.18	2.50	10.63	89.54	96.09	89.33	94.91	89.11	93.48	88.90	91.73	88.69	89.59	88.48	88.48
133.16	15.02	3.00	10.35	89.50	96.00	89.29	94.79	89.07	93.33	88.86	91.54	88.64	89.36	88.42	88.42
132.27	18.02	3.50	10.06	89.47	95.90	89.25	94.67	89.03	93.17	88.81	91.34	88.59	89.11	88.37	88.37
131.35	21.20	4.00	9.77	89.43	95.80	89.21	94.54	88.98	93.00	88.76	91.13	88.53	88.84	88.30	88.30
130.4	24.57	4.50	9.48	89.40	95.69	89.16	94.40	88.93	92.83	88.70	90.91	88.47	88.57	88.24	88.24
129.43	28.16	5.00	9.20	89.35	95.57	89.12	94.25	88.88	92.64	88.64	90.67	88.41	88.41	88.17	88.17
128.42	31.97	5.50	8.91	89.31	95.45	89.07	94.09	88.82	92.44	88.58	90.42	88.34	88.34	88.09	88.09
127.37	36.04	6.00	8.62	89.26	95.32	89.01	93.93	88.76	92.23	88.51	90.15	88.26	88.26	88.01	88.01
126.3	40.39	6.50	8.33	89.21	95.18	88.96	93.75	88.70	92.00	88.44	89.86	88.19	88.19	87.93	87.93
125.18	45.05	7.00	8.05	89.16	95.02	88.90	93.55	88.63	91.75	88.37	89.56	88.10	88.10	87.84	87.84
124.02	50.05	7.50	7.76	89.10	94.86	88.83	93.35	88.56	91.49	88.29	89.22	88.01	88.01	87.74	87.74
122.82	55.45	8.00	7.47	89.04	94.69	88.76	93.12	88.48	91.21	88.20	88.87	87.92	87.92	87.63	87.63
121.57	61.27	8.50	7.18	88.98	94.50	88.69	92.88	88.40	90.91	88.10	88.48	87.81	87.81	87.52	87.52
120.27	67.57	9.00	6.90	88.91	94.30	88.60	92.62	88.30	90.58	88.00	88.07	87.70	87.70	87.40	87.40
118.91	74.43	9.50	6.61	88.83	94.07	88.51	92.34	88.20	90.22	87.89	87.89	87.58	87.58	87.26	87.26
117.5	81.91	10.00	6.32	88.74	93.83	88.42	92.03	88.09	89.82	87.77	87.77	87.44	87.44	87.12	87.12
116.02	90.10	10.50	6.04	88.65	93.57	88.31	91.69	87.97	89.40	87.63	87.63	87.30	87.30	86.96	86.96
114.47	99.11	11.00	5.75	88.55	93.28	88.19	91.32	87.84	88.92	87.49	87.49	87.13	87.13	86.78	86.78
112.85	109.07	11.50	5.46	88.43	92.95	88.06	90.91	87.69	88.40	87.33	87.33	86.96	86.96	86.59	86.59
111.13	120.13	12.00	5.17	88.31	92.60	87.92	90.45	87.53	87.82	87.15	87.15	86.76	86.76	86.37	86.37
109.33	132.50	12.50	4.89	88.17	92.20	87.76	89.94	87.35	87.35	86.94	86.94	86.54	86.54	86.13	86.13
107.42	146.41	13.00	4.60	88.01	91.75	87.58	89.37	87.15	87.15	86.72	86.72	86.29	86.29	85.86	85.86
105.39	162.18	13.50	4.31	87.83	91.24	87.37	88.72	86.92	86.92	86.46	86.46	86.00	86.00	85.55	85.55
103.23	180.20	14.00	4.02	87.62	90.65	87.14	87.97	86.65	86.65	86.17	86.17	85.68	85.68	85.20	85.20
100.92	200.99	14.50	3.74	87.38	89.98	86.87	87.11	86.35	86.35	85.83	85.83	85.31	85.31	84.79	84.79
98.43	225.25	15.00	3.45	87.11	89.20	86.55	86.55	85.99	85.99	85.43	85.43	84.87	84.87	84.31	84.31



**Table A4.7b. Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub> = 14.696 psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
138.02	0.00	0.00	12.07	88.62	88.14	87.66	87.18	86.69	86.20	85.22	84.24	83.25	82.25	81.24	79.20
137.26	2.20	0.50	11.78	88.58	88.09	87.60	87.10	86.61	86.11	85.12	84.11	83.10	82.08	81.06	78.98
136.49	4.50	1.00	11.50	88.53	88.03	87.53	87.03	86.52	86.02	85.00	83.98	82.95	81.91	80.87	78.75
135.69	6.93	1.50	11.21	88.48	87.97	87.46	86.95	86.44	85.92	84.88	83.84	82.79	81.73	80.67	78.51
134.87	9.48	2.00	10.92	88.43	87.91	87.39	86.87	86.34	85.82	84.76	83.69	82.62	81.54	80.45	78.25
134.03	12.18	2.50	10.63	88.37	87.84	87.31	86.78	86.24	85.71	84.63	83.54	82.44	81.34	80.23	77.99
133.16	15.02	3.00	10.35	88.32	87.77	87.23	86.69	86.14	85.59	84.49	83.38	82.26	81.13	80.00	77.70
132.27	18.02	3.50	10.06	88.26	87.70	87.15	86.59	86.03	85.47	84.34	83.20	82.06	80.91	79.75	77.40
131.35	21.20	4.00	9.77	88.19	87.62	87.05	86.48	85.91	85.34	84.18	83.02	81.85	80.67	79.49	77.09
130.4	24.57	4.50	9.48	88.12	87.54	86.96	86.37	85.79	85.20	84.02	82.83	81.63	80.42	79.21	76.75
129.43	28.16	5.00	9.20	88.05	87.45	86.86	86.26	85.66	85.05	83.84	82.62	81.39	80.16	78.91	76.39
128.42	31.97	5.50	8.91	87.97	87.36	86.75	86.13	85.52	84.90	83.65	82.40	81.14	79.87	78.59	76.01
127.37	36.04	6.00	8.62	87.89	87.26	86.63	86.00	85.37	84.73	83.45	82.17	80.87	79.57	78.26	75.61
126.3	40.39	6.50	8.33	87.80	87.15	86.51	85.86	85.21	84.55	83.24	81.92	80.59	79.25	77.90	75.17
125.18	45.05	7.00	8.05	87.70	87.04	86.37	85.70	85.03	84.36	83.01	81.65	80.28	78.90	77.51	74.71
124.02	50.05	7.50	7.76	87.60	86.92	86.23	85.54	84.85	84.16	82.76	81.36	79.95	78.53	77.10	74.21
122.82	55.45	8.00	7.47	87.49	86.79	86.08	85.37	84.65	83.94	82.50	81.05	79.60	78.13	76.65	73.67
121.57	61.27	8.50	7.18	87.37	86.64	85.91	85.18	84.44	83.70	82.21	80.72	79.21	77.70	76.17	73.09
120.27	67.57	9.00	6.90	87.25	86.49	85.73	84.97	84.21	83.44	81.90	80.36	78.80	77.23	75.65	72.46
118.91	74.43	9.50	6.61	87.11	86.32	85.53	84.75	83.95	83.16	81.57	79.96	78.35	76.72	75.08	71.77
117.5	81.91	10.00	6.32	86.95	86.14	85.32	84.50	83.68	82.85	81.20	79.53	77.85	76.17	74.46	71.03
116.02	90.10	10.50	6.04	86.79	85.94	85.09	84.23	83.38	82.52	80.80	79.06	77.31	75.56	73.79	70.21
114.47	99.11	11.00	5.75	86.60	85.72	84.83	83.94	83.05	82.15	80.35	78.54	76.72	74.89	73.04	69.31
112.85	109.07	11.50	5.46	86.40	85.47	84.55	83.61	82.68	81.74	79.86	77.97	76.07	74.15	72.22	68.32
111.13	120.13	12.00	5.17	86.18	85.20	84.23	83.25	82.27	81.29	79.32	77.33	75.34	73.33	71.30	67.21
109.33	132.50	12.50	4.89	85.92	84.90	83.88	82.85	81.82	80.79	78.71	76.62	74.52	72.41	70.28	65.98
107.42	146.41	13.00	4.60	85.64	84.56	83.48	82.40	81.31	80.22	78.03	75.82	73.61	71.38	69.13	64.59
105.39	162.18	13.50	4.31	85.32	84.18	83.03	81.88	80.73	79.57	77.25	74.92	72.57	70.21	67.83	63.02
103.23	180.20	14.00	4.02	84.95	83.73	82.51	81.29	80.07	78.84	76.37	73.88	71.38	68.87	66.34	61.22
100.92	200.99	14.50	3.74	84.53	83.23	81.92	80.61	79.30	77.99	75.34	72.69	70.01	67.32	64.62	59.15
98.43	225.25	15.00	3.45	84.03	82.63	81.23	79.82	78.41	76.99	74.15	71.29	68.42	65.52	62.61	56.73

**Table A4.8a. Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [60°F ≤ ΔT ≤ 110°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 60°F		ΔT = 70°F		ΔT = 80°F		ΔT = 90°F		ΔT = 100°F		ΔT = 110°F	
				η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing
138.02	0.00	0.00	12.07	89.83	96.63	89.64	95.56	89.44	94.27	89.25	92.68	89.06	90.75	88.87	88.87
137.26	2.20	0.50	11.78	89.80	96.56	89.61	95.48	89.42	94.15	89.22	92.54	89.03	90.57	88.83	88.83
136.49	4.50	1.00	11.50	89.78	96.49	89.58	95.39	89.39	94.04	89.19	92.39	88.99	90.39	88.79	88.79
135.69	6.93	1.50	11.21	89.76	96.42	89.56	95.29	89.35	93.91	89.15	92.24	88.95	90.19	88.74	88.74
134.87	9.48	2.00	10.92	89.73	96.34	89.53	95.19	89.32	93.78	89.11	92.07	88.91	89.98	88.70	88.70
134.03	12.18	2.50	10.63	89.71	96.26	89.50	95.08	89.29	93.65	89.07	91.90	88.86	89.76	88.65	88.65
133.16	15.02	3.00	10.35	89.68	96.17	89.46	94.97	89.25	93.50	89.03	91.71	88.82	89.53	88.60	88.60
132.27	18.02	3.50	10.06	89.65	96.08	89.43	94.85	89.21	93.35	88.99	91.52	88.77	89.29	88.55	88.55
131.35	21.20	4.00	9.77	89.62	95.98	89.39	94.72	89.17	93.19	88.94	91.32	88.72	89.03	88.49	88.49
130.4	24.57	4.50	9.48	89.59	95.88	89.36	94.59	89.12	93.02	88.89	91.10	88.66	88.76	88.43	88.43
129.43	28.16	5.00	9.20	89.55	95.77	89.31	94.45	89.08	92.84	88.84	90.87	88.60	88.60	88.36	88.36
128.42	31.97	5.50	8.91	89.51	95.65	89.27	94.30	89.03	92.64	88.78	90.62	88.54	88.54	88.30	88.30
127.37	36.04	6.00	8.62	89.47	95.53	89.22	94.13	88.97	92.44	88.72	90.36	88.47	88.47	88.22	88.22
126.3	40.39	6.50	8.33	89.43	95.39	89.17	93.96	88.92	92.22	88.66	90.08	88.40	88.40	88.15	88.15
125.18	45.05	7.00	8.05	89.39	95.25	89.12	93.78	88.86	91.98	88.59	89.78	88.33	88.33	88.06	88.06
124.02	50.05	7.50	7.76	89.34	95.09	89.06	93.58	88.79	91.73	88.52	89.46	88.25	88.25	87.97	87.97
122.82	55.45	8.00	7.47	89.28	94.93	89.00	93.36	88.72	91.45	88.44	89.11	88.16	88.16	87.88	87.88
121.57	61.27	8.50	7.18	89.23	94.75	88.94	93.13	88.65	91.16	88.35	88.73	88.06	88.06	87.77	87.77
120.27	67.57	9.00	6.90	89.17	94.56	88.86	92.88	88.56	90.84	88.26	88.33	87.96	87.96	87.66	87.66
118.91	74.43	9.50	6.61	89.10	94.35	88.79	92.61	88.47	90.49	88.16	88.16	87.85	87.85	87.54	87.54
117.5	81.91	10.00	6.32	89.03	94.12	88.70	92.31	88.38	90.11	88.05	88.05	87.73	87.73	87.40	87.40
116.02	90.10	10.50	6.04	88.95	93.87	88.61	91.99	88.27	89.69	87.93	87.93	87.59	87.59	87.25	87.25
114.47	99.11	11.00	5.75	88.86	93.59	88.51	91.63	88.15	89.24	87.80	87.80	87.45	87.45	87.09	87.09
112.85	109.07	11.50	5.46	88.76	93.28	88.39	91.24	88.02	88.73	87.65	87.65	87.28	87.28	86.91	86.91
111.13	120.13	12.00	5.17	88.65	92.94	88.27	90.80	87.88	88.17	87.49	87.49	87.10	87.10	86.72	86.72
109.33	132.50	12.50	4.89	88.53	92.56	88.12	90.31	87.72	87.72	87.31	87.31	86.90	86.90	86.49	86.49
107.42	146.41	13.00	4.60	88.40	92.14	87.97	89.76	87.54	87.54	87.11	87.11	86.68	86.68	86.25	86.25
105.39	162.18	13.50	4.31	88.24	91.65	87.79	89.13	87.33	87.33	86.88	86.88	86.42	86.42	85.96	85.96
103.23	180.20	14.00	4.02	88.07	91.10	87.58	88.42	87.10	87.10	86.61	86.61	86.13	86.13	85.64	85.64
100.92	200.99	14.50	3.74	87.86	90.46	87.34	87.59	86.83	86.83	86.31	86.31	85.79	85.79	85.27	85.27
98.43	225.25	15.00	3.45	87.63	89.71	87.07	87.07	86.51	86.51	85.95	85.95	85.39	85.39	84.83	84.83

**Table A4.8b. Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 30°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
138.02	0.00	0.00	12.07	88.58	88.10	87.62	87.13	86.65	86.16	85.18	84.19	83.20	82.20	81.19	79.15
137.26	2.20	0.50	11.78	88.54	88.05	87.55	87.06	86.57	86.07	85.07	84.07	83.05	82.03	81.01	78.93
136.49	4.50	1.00	11.50	88.49	87.99	87.49	86.99	86.48	85.97	84.96	83.93	82.90	81.86	80.81	78.70
135.69	6.93	1.50	11.21	88.44	87.93	87.42	86.91	86.39	85.88	84.84	83.79	82.74	81.68	80.61	78.45
134.87	9.48	2.00	10.92	88.39	87.87	87.35	86.82	86.30	85.77	84.71	83.65	82.57	81.49	80.40	78.20
134.03	12.18	2.50	10.63	88.33	87.80	87.27	86.73	86.20	85.66	84.58	83.49	82.40	81.29	80.18	77.93
133.16	15.02	3.00	10.35	88.28	87.73	87.19	86.64	86.09	85.54	84.44	83.33	82.21	81.08	79.94	77.65
132.27	18.02	3.50	10.06	88.21	87.66	87.10	86.54	85.98	85.42	84.29	83.16	82.01	80.86	79.70	77.35
131.35	21.20	4.00	9.77	88.15	87.58	87.01	86.44	85.87	85.29	84.14	82.97	81.80	80.62	79.43	77.03
130.4	24.57	4.50	9.48	88.08	87.50	86.92	86.33	85.74	85.15	83.97	82.78	81.58	80.37	79.15	76.69
129.43	28.16	5.00	9.20	88.01	87.41	86.81	86.21	85.61	85.01	83.79	82.57	81.34	80.10	78.86	76.33
128.42	31.97	5.50	8.91	87.93	87.32	86.70	86.09	85.47	84.85	83.61	82.35	81.09	79.82	78.54	75.95
127.37	36.04	6.00	8.62	87.85	87.22	86.59	85.96	85.32	84.68	83.41	82.12	80.82	79.52	78.20	75.55
126.3	40.39	6.50	8.33	87.76	87.11	86.46	85.81	85.16	84.51	83.19	81.87	80.54	79.20	77.84	75.11
125.18	45.05	7.00	8.05	87.66	87.00	86.33	85.66	84.99	84.32	82.96	81.60	80.23	78.85	77.46	74.65
124.02	50.05	7.50	7.76	87.56	86.88	86.19	85.50	84.81	84.11	82.72	81.31	79.90	78.48	77.04	74.15
122.82	55.45	8.00	7.47	87.45	86.74	86.03	85.32	84.61	83.89	82.45	81.00	79.54	78.08	76.60	73.61
121.57	61.27	8.50	7.18	87.33	86.60	85.87	85.13	84.39	83.65	82.17	80.67	79.16	77.64	76.12	73.03
120.27	67.57	9.00	6.90	87.20	86.45	85.69	84.93	84.16	83.39	81.86	80.31	78.75	77.18	75.59	72.40
118.91	74.43	9.50	6.61	87.06	86.28	85.49	84.70	83.91	83.11	81.52	79.91	78.29	76.67	75.03	71.71
117.5	81.91	10.00	6.32	86.91	86.10	85.28	84.46	83.63	82.81	81.15	79.48	77.80	76.11	74.41	70.97
116.02	90.10	10.50	6.04	86.75	85.90	85.04	84.19	83.33	82.47	80.75	79.01	77.26	75.50	73.73	70.15
114.47	99.11	11.00	5.75	86.56	85.68	84.79	83.89	83.00	82.10	80.30	78.49	76.67	74.83	72.98	69.25
112.85	109.07	11.50	5.46	86.36	85.43	84.50	83.57	82.63	81.70	79.81	77.92	76.01	74.09	72.16	68.25
111.13	120.13	12.00	5.17	86.13	85.16	84.19	83.21	82.23	81.24	79.27	77.28	75.28	73.27	71.24	67.15
109.33	132.50	12.50	4.89	85.88	84.86	83.83	82.80	81.77	80.74	78.66	76.57	74.47	72.35	70.22	65.91
107.42	146.41	13.00	4.60	85.60	84.52	83.44	82.35	81.26	80.17	77.98	75.77	73.55	71.32	69.07	64.52
105.39	162.18	13.50	4.31	85.28	84.13	82.98	81.83	80.68	79.52	77.20	74.86	72.51	70.15	67.76	62.95
103.23	180.20	14.00	4.02	84.91	83.69	82.47	81.25	80.02	78.79	76.32	73.83	71.33	68.81	66.27	61.15
100.92	200.99	14.50	3.74	84.49	83.18	81.88	80.57	79.25	77.94	75.29	72.63	69.96	67.26	64.55	59.07
98.43	225.25	15.00	3.45	83.99	82.59	81.18	79.77	78.36	76.94	74.10	71.24	68.36	65.46	62.54	56.65

**Table A4.9a. Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [50°F ≤ ΔT ≤ 100°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 50°F		ΔT = 60°F		ΔT = 70°F		ΔT = 80°F		ΔT = 90°F		ΔT = 100°F	
				η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing
138.02	0.00	0.00	12.07	89.98	96.78	89.79	95.72	89.59	94.42	89.40	92.83	89.21	90.90	89.02	89.02
137.26	2.20	0.50	11.78	89.96	96.72	89.76	95.63	89.57	94.31	89.37	92.70	89.18	90.73	88.98	88.98
136.49	4.50	1.00	11.50	89.94	96.65	89.74	95.54	89.54	94.20	89.34	92.55	89.15	90.54	88.95	88.95
135.69	6.93	1.50	11.21	89.92	96.58	89.72	95.45	89.52	94.08	89.31	92.40	89.11	90.35	88.91	88.91
134.87	9.48	2.00	10.92	89.90	96.51	89.69	95.35	89.49	93.95	89.28	92.24	89.07	90.15	88.87	88.87
134.03	12.18	2.50	10.63	89.88	96.43	89.67	95.25	89.46	93.82	89.24	92.07	89.03	89.93	88.82	88.82
133.16	15.02	3.00	10.35	89.85	96.35	89.64	95.14	89.42	93.68	89.21	91.89	88.99	89.71	88.78	88.78
132.27	18.02	3.50	10.06	89.83	96.26	89.61	95.03	89.39	93.53	89.17	91.70	88.95	89.47	88.73	88.73
131.35	21.20	4.00	9.77	89.80	96.17	89.58	94.91	89.35	93.37	89.13	91.50	88.90	89.22	88.67	88.67
130.4	24.57	4.50	9.48	89.78	96.07	89.55	94.78	89.31	93.21	89.08	91.29	88.85	88.95	88.62	88.62
129.43	28.16	5.00	9.20	89.75	95.96	89.51	94.64	89.27	93.03	89.04	91.06	88.80	88.80	88.56	88.56
128.42	31.97	5.50	8.91	89.72	95.85	89.47	94.50	89.23	92.85	88.99	90.83	88.74	88.74	88.50	88.50
127.37	36.04	6.00	8.62	89.68	95.73	89.43	94.34	89.18	92.65	88.93	90.57	88.68	88.68	88.43	88.43
126.3	40.39	6.50	8.33	89.65	95.61	89.39	94.18	89.13	92.43	88.88	90.30	88.62	88.62	88.36	88.36
125.18	45.05	7.00	8.05	89.61	95.47	89.35	94.00	89.08	92.20	88.82	90.00	88.55	88.55	88.29	88.29
124.02	50.05	7.50	7.76	89.57	95.33	89.30	93.81	89.02	91.96	88.75	89.69	88.48	88.48	88.20	88.20
122.82	55.45	8.00	7.47	89.53	95.17	89.24	93.61	88.96	91.69	88.68	89.35	88.40	88.40	88.12	88.12
121.57	61.27	8.50	7.18	89.48	95.00	89.19	93.38	88.90	91.41	88.61	88.99	88.31	88.31	88.02	88.02
120.27	67.57	9.00	6.90	89.43	94.82	89.13	93.14	88.82	91.10	88.52	88.59	88.22	88.22	87.92	87.92
118.91	74.43	9.50	6.61	89.37	94.62	89.06	92.88	88.75	90.76	88.43	88.43	88.12	88.12	87.81	87.81
117.5	81.91	10.00	6.32	89.31	94.40	88.99	92.60	88.66	90.39	88.34	88.34	88.01	88.01	87.69	87.69
116.02	90.10	10.50	6.04	89.24	94.16	88.91	92.29	88.57	89.99	88.23	88.23	87.89	87.89	87.55	87.55
114.47	99.11	11.00	5.75	89.17	93.90	88.82	91.94	88.46	89.55	88.11	88.11	87.76	87.76	87.41	87.41
112.85	109.07	11.50	5.46	89.09	93.61	88.72	91.57	88.35	89.06	87.98	87.98	87.61	87.61	87.24	87.24
111.13	120.13	12.00	5.17	89.00	93.29	88.61	91.14	88.23	88.52	87.84	87.84	87.45	87.45	87.06	87.06
109.33	132.50	12.50	4.89	88.90	92.93	88.49	90.67	88.08	88.08	87.68	87.68	87.27	87.27	86.86	86.86
107.42	146.41	13.00	4.60	88.79	92.53	88.36	90.15	87.93	87.93	87.50	87.50	87.07	87.07	86.63	86.63
105.39	162.18	13.50	4.31	88.66	92.07	88.20	89.55	87.75	87.75	87.29	87.29	86.83	86.83	86.38	86.38
103.23	180.20	14.00	4.02	88.51	91.54	88.03	88.86	87.54	87.54	87.06	87.06	86.57	86.57	86.08	86.08
100.92	200.99	14.50	3.74	88.34	90.94	87.82	88.07	87.30	87.30	86.78	86.78	86.26	86.26	85.74	85.74
98.43	225.25	15.00	3.45	88.14	90.23	87.59	87.59	87.03	87.03	86.47	86.47	85.91	85.91	85.35	85.35

**Table A4.9b. Nat Gas; [HHV = 1080 Btu/ft<sup>3</sup>]; [T<sub>(ambient)</sub> = 40°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 68.75%; H<sub>2</sub> – 22.3%; O<sub>2</sub> – 0.37%; S<sub>2</sub> – 0.06%; N<sub>2</sub> – 3.3%; CO<sub>2</sub> – 5.2%; H<sub>2</sub>O – 0.02%

**P<sub>(ambient)</sub>** = 14.696 psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
138.02	0.00	0.00	12.07	88.54	88.06	87.57	87.09	86.60	86.11	85.13	84.14	83.15	82.15	81.14	79.09
137.26	2.20	0.50	11.78	88.49	88.00	87.51	87.02	86.52	86.02	85.02	84.02	83.00	81.98	80.95	78.87
136.49	4.50	1.00	11.50	88.45	87.95	87.45	86.94	86.44	85.93	84.91	83.89	82.85	81.81	80.76	78.64
135.69	6.93	1.50	11.21	88.40	87.89	87.38	86.86	86.35	85.83	84.79	83.75	82.69	81.63	80.56	78.40
134.87	9.48	2.00	10.92	88.35	87.83	87.30	86.78	86.25	85.73	84.67	83.60	82.52	81.44	80.35	78.14
134.03	12.18	2.50	10.63	88.29	87.76	87.23	86.69	86.15	85.62	84.53	83.44	82.35	81.24	80.13	77.87
133.16	15.02	3.00	10.35	88.23	87.69	87.15	86.60	86.05	85.50	84.39	83.28	82.16	81.03	79.89	77.59
132.27	18.02	3.50	10.06	88.17	87.62	87.06	86.50	85.94	85.38	84.25	83.11	81.96	80.81	79.64	77.29
131.35	21.20	4.00	9.77	88.11	87.54	86.97	86.40	85.82	85.25	84.09	82.92	81.75	80.57	79.38	76.97
130.4	24.57	4.50	9.48	88.04	87.46	86.87	86.29	85.70	85.11	83.92	82.73	81.53	80.32	79.10	76.64
129.43	28.16	5.00	9.20	87.97	87.37	86.77	86.17	85.57	84.96	83.75	82.52	81.29	80.05	78.80	76.28
128.42	31.97	5.50	8.91	87.89	87.28	86.66	86.04	85.43	84.81	83.56	82.30	81.04	79.77	78.49	75.90
127.37	36.04	6.00	8.62	87.81	87.18	86.54	85.91	85.28	84.64	83.36	82.07	80.77	79.47	78.15	75.49
126.3	40.39	6.50	8.33	87.72	87.07	86.42	85.77	85.12	84.46	83.15	81.82	80.49	79.14	77.79	75.05
125.18	45.05	7.00	8.05	87.62	86.96	86.29	85.62	84.94	84.27	82.92	81.55	80.18	78.80	77.40	74.59
124.02	50.05	7.50	7.76	87.52	86.83	86.14	85.45	84.76	84.07	82.67	81.26	79.85	78.42	76.99	74.09
122.82	55.45	8.00	7.47	87.41	86.70	85.99	85.28	84.56	83.85	82.40	80.95	79.49	78.02	76.54	73.55
121.57	61.27	8.50	7.18	87.29	86.56	85.82	85.09	84.35	83.61	82.12	80.62	79.11	77.59	76.06	72.97
120.27	67.57	9.00	6.90	87.16	86.40	85.64	84.88	84.12	83.35	81.81	80.26	78.69	77.12	75.54	72.34
118.91	74.43	9.50	6.61	87.02	86.24	85.45	84.66	83.86	83.07	81.47	79.86	78.24	76.61	74.97	71.65
117.5	81.91	10.00	6.32	86.87	86.05	85.23	84.41	83.59	82.76	81.10	79.43	77.75	76.05	74.35	70.90
116.02	90.10	10.50	6.04	86.70	85.85	85.00	84.14	83.29	82.43	80.70	78.96	77.21	75.45	73.67	70.09
114.47	99.11	11.00	5.75	86.52	85.63	84.74	83.85	82.96	82.06	80.25	78.44	76.61	74.78	72.92	69.18
112.85	109.07	11.50	5.46	86.32	85.39	84.46	83.52	82.59	81.65	79.76	77.87	75.96	74.03	72.10	68.19
111.13	120.13	12.00	5.17	86.09	85.12	84.14	83.16	82.18	81.20	79.22	77.23	75.23	73.21	71.18	67.08
109.33	132.50	12.50	4.89	85.84	84.81	83.79	82.76	81.73	80.69	78.61	76.52	74.41	72.29	70.16	65.85
107.42	146.41	13.00	4.60	85.56	84.47	83.39	82.30	81.21	80.12	77.93	75.72	73.50	71.26	69.01	64.46
105.39	162.18	13.50	4.31	85.23	84.09	82.94	81.79	80.63	79.48	77.15	74.81	72.46	70.09	67.70	62.88
103.23	180.20	14.00	4.02	84.87	83.65	82.43	81.20	79.97	78.74	76.26	73.77	71.27	68.75	66.21	61.08
100.92	200.99	14.50	3.74	84.44	83.14	81.83	80.52	79.21	77.89	75.24	72.58	69.90	67.20	64.48	59.00
98.43	225.25	15.00	3.45	83.95	82.54	81.14	79.73	78.31	76.89	74.05	71.18	68.30	65.40	62.47	56.58

**Table A4.10a. #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [ $T_{\text{ambient}} = 20^{\circ}\text{F}$ ]; [ $70^{\circ}\text{F} \leq \Delta T \leq 120^{\circ}\text{F}$ ].**

**Ultimate Analysis:** Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%

$P_{\text{ambient}} = 14.696$  psia

Flue Gas Dew Pt ( $^{\circ}\text{F}$ )	% Excess Air	% $\text{O}_2$ (dry)	% $\text{CO}_2$ (dry)	$\Delta T = 70^{\circ}\text{F}$		$\Delta T = 80^{\circ}\text{F}$		$\Delta T = 90^{\circ}\text{F}$		$\Delta T = 100^{\circ}\text{F}$		$\Delta T = 110^{\circ}\text{F}$		$\Delta T = 120^{\circ}\text{F}$	
				$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing
120.963	0	0	0	92.47	96.177	92.265	95.058	92.06	93.689	91.854	92.015	91.649	91.649	91.443	91.443
120.196	2.285	0.5	15.309	92.441	96.094	92.232	94.952	92.022	93.555	91.813	91.846	91.603	91.603	91.393	91.393
119.410	4.685	1	14.936	92.410	96.008	92.197	94.841	91.983	93.415	91.769	91.769	91.555	91.555	91.341	91.341
118.604	7.207	1.5	14.562	92.378	95.916	92.160	94.725	91.942	93.267	91.723	91.723	91.505	91.505	91.285	91.285
117.778	9.862	2	14.189	92.344	95.820	92.121	94.602	91.898	93.112	91.675	91.675	91.451	91.451	91.227	91.227
116.930	12.661	2.5	13.816	92.309	95.719	92.081	94.473	91.853	92.948	91.624	91.624	91.395	91.395	91.166	91.166
116.059	15.616	3	13.442	92.271	95.613	92.038	94.337	91.804	92.775	91.57	91.57	91.336	91.336	91.102	91.102
115.165	18.739	3.5	13.069	92.231	95.500	91.992	94.193	91.753	92.592	91.513	91.513	91.274	91.274	91.034	91.034
114.245	22.046	4	12.695	92.189	95.380	91.944	94.04	91.699	92.399	91.453	91.453	91.207	91.207	90.961	90.961
113.298	25.553	4.5	12.322	92.144	95.254	91.893	93.878	91.641	92.194	91.389	91.389	91.137	91.137	90.885	90.885
112.323	29.279	5	11.949	92.097	95.119	91.839	93.706	91.58	91.976	91.322	91.322	91.063	91.063	90.803	90.803
111.319	33.246	5.5	11.575	92.046	94.976	91.781	93.523	91.515	91.743	91.249	91.249	90.983	90.983	90.717	90.717
110.282	37.477	6	11.202	91.993	94.823	91.720	93.328	91.446	91.496	91.172	91.172	90.899	90.899	90.624	90.624
109.212	42.001	6.5	10.828	91.935	94.659	91.654	93.119	91.372	91.372	91.09	91.09	90.808	90.808	90.525	90.525
108.106	46.847	7	10.455	91.873	94.484	91.583	92.896	91.293	91.293	91.002	91.002	90.711	90.711	90.42	90.42
106.961	52.052	7.5	10.082	91.807	94.296	91.507	92.656	91.207	91.207	90.907	90.907	90.607	90.607	90.306	90.306
105.775	57.658	8	9.708	91.736	94.094	91.426	92.397	91.116	91.116	90.805	90.805	90.494	90.494	90.183	90.183
104.546	63.712	8.5	9.335	91.659	93.875	91.338	92.118	91.017	91.017	90.695	90.695	90.373	90.373	90.051	90.051
103.268	70.270	9	8.962	91.575	93.638	91.242	91.815	90.909	90.909	90.576	90.576	90.242	90.242	89.908	89.908
101.939	77.399	9.5	8.588	91.484	93.380	91.139	91.486	90.792	90.792	90.446	90.446	90.099	90.099	89.752	89.752
100.555	85.176	10	8.215	91.385	93.099	91.025	91.127	90.665	90.665	90.304	90.304	89.944	89.944	89.582	89.582
99.110	93.694	10.5	7.841	91.277	92.792	90.901	90.901	90.526	90.526	90.149	90.149	89.773	89.773	89.396	89.396
97.600	103.063	11	7.468	91.157	92.453	90.765	90.765	90.372	90.372	89.979	89.979	89.585	89.585	89.192	89.192
96.017	113.419	11.5	7.095	91.026	92.079	90.614	90.614	90.203	90.203	89.791	89.791	89.378	89.378	88.965	88.965
94.354	124.925	12	6.721	90.879	91.663	90.447	90.447	90.014	90.014	89.581	89.581	89.148	89.148	88.714	88.714
92.604	137.785	12.5	6.348	90.715	91.199	90.260	90.26	89.804	89.804	89.347	89.347	88.89	88.89	88.433	88.433
90.755	152.252	13	5.974	90.531	90.676	90.049	90.049	89.567	89.567	89.084	89.084	88.601	88.601	88.117	88.117
88.797	168.649	13.5	5.601	90.322	90.322	89.810	89.81	89.298	89.298	88.785	88.785	88.272	88.272	87.759	87.759
86.714	187.387	14	5.228	90.084	90.084	89.538	89.538	88.991	88.991	88.444	88.444	87.897	87.897	87.349	87.349
84.491	209.009	14.5	4.854	89.808	89.808	89.223	89.223	88.637	88.637	88.051	88.051	87.464	87.464	86.877	86.877
82.104	234.234	15	4.481	89.487	89.487	88.856	88.856	88.224	88.224	87.592	87.592	86.959	86.959	86.326	86.326

**Table A4.10b. #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%  
**P<sub>(ambient)</sub> = 14.696 psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
120.963	0	0	0	91.34	90.823	90.305	89.785	89.263	88.739	87.685	86.622	85.551	84.472	83.385	81.184
120.196	2.285	0.5	15.309	91.288	90.761	90.232	89.702	89.169	88.634	87.559	86.475	85.383	84.283	83.173	80.929
119.41	4.685	1	14.936	91.233	90.695	90.156	89.614	89.07	88.525	87.427	86.321	85.207	84.084	82.952	80.661
118.604	7.207	1.5	14.562	91.176	90.626	90.075	89.522	88.967	88.41	87.289	86.159	85.021	83.874	82.719	80.38
117.778	9.862	2	14.189	91.115	90.554	89.991	89.425	88.858	88.288	87.143	85.989	84.826	83.654	82.473	80.084
116.93	12.661	2.5	13.816	91.052	90.477	89.901	89.323	88.743	88.16	86.989	85.809	84.62	83.422	82.215	79.772
116.059	15.616	3	13.442	90.984	90.397	89.807	89.215	88.621	88.025	86.827	85.619	84.403	83.177	81.942	79.443
115.165	18.739	3.5	13.069	90.913	90.311	89.707	89.101	88.493	87.883	86.655	85.419	84.173	82.918	81.653	79.095
114.245	22.046	4	12.695	90.838	90.221	89.602	88.981	88.357	87.732	86.474	85.207	83.93	82.644	81.347	78.726
113.298	25.553	4.5	12.322	90.758	90.125	89.49	88.853	88.213	87.571	86.281	84.981	83.672	82.353	81.023	78.335
112.323	29.279	5	11.949	90.674	90.023	89.371	88.717	88.06	87.401	86.076	84.742	83.398	82.043	80.679	77.92
111.319	33.246	5.5	11.575	90.583	89.915	89.245	88.572	87.897	87.22	85.859	84.487	83.106	81.714	80.312	77.477
110.282	37.477	6	11.202	90.487	89.799	89.11	88.418	87.723	87.027	85.626	84.216	82.795	81.363	79.921	77.006
109.212	42.001	6.5	10.828	90.384	89.676	88.965	88.253	87.538	86.82	85.378	83.925	82.462	80.988	79.504	76.501
108.106	46.847	7	10.455	90.274	89.543	88.811	88.076	87.339	86.599	85.112	83.614	82.106	80.586	79.056	75.961
106.961	52.052	7.5	10.082	90.155	89.401	88.645	87.886	87.125	86.361	84.826	83.28	81.723	80.154	78.575	75.381
105.775	57.658	8	9.708	90.028	89.248	88.466	87.681	86.894	86.105	84.518	82.92	81.31	79.689	78.057	74.756
104.546	63.712	8.5	9.335	89.89	89.083	88.273	87.461	86.646	85.828	84.185	82.531	80.865	79.187	77.497	74.081
103.268	70.27	9	8.962	89.741	88.903	88.064	87.221	86.376	85.529	83.825	82.11	80.383	78.643	76.891	73.35
101.939	77.399	9.5	8.588	89.578	88.709	87.836	86.961	86.084	85.203	83.434	81.652	79.858	78.052	76.232	72.555
100.555	85.176	10	8.215	89.401	88.496	87.588	86.677	85.764	84.848	83.006	81.153	79.286	77.407	75.514	71.688
99.11	93.694	10.5	7.841	89.208	88.263	87.316	86.367	85.414	84.459	82.539	80.606	78.66	76.7	74.727	70.739
97.6	103.063	11	7.468	88.994	88.007	87.017	86.025	85.029	84.031	82.024	80.004	77.97	75.923	73.861	69.694
96.017	113.419	11.5	7.095	88.759	87.724	86.687	85.647	84.604	83.558	81.455	79.339	77.209	75.064	72.904	68.54
94.354	124.925	12	6.721	88.497	87.41	86.32	85.227	84.131	83.032	80.823	78.6	76.362	74.109	71.841	67.257
92.604	137.785	12.5	6.348	88.204	87.059	85.91	84.758	83.603	82.445	80.117	77.774	75.416	73.042	70.652	65.823
90.755	152.252	13	5.974	87.875	86.663	85.448	84.23	83.009	81.784	79.322	76.845	74.352	71.842	69.316	64.21
88.797	168.649	13.5	5.601	87.502	86.215	84.925	83.632	82.335	81.035	78.422	75.792	73.146	70.482	67.8	62.383
86.714	187.387	14	5.228	87.075	85.703	84.328	82.948	81.566	80.179	77.392	74.589	71.768	68.928	66.069	60.293
84.491	209.009	14.5	4.854	86.583	85.112	83.638	82.16	80.677	79.191	76.205	73.201	70.177	67.134	64.071	57.883
82.104	234.234	15	4.481	86.009	84.423	82.833	81.239	79.641	78.039	74.819	71.581	68.322	65.042	61.74	55.071

**Table A4.11a. #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [ $T_{\text{ambient}} = 30^{\circ}\text{F}$ ]; [ $60^{\circ}\text{F} \leq \Delta T \leq 110^{\circ}\text{F}$ ].**

**Ultimate Analysis:** Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%

$P_{\text{ambient}} = 14.696$  psia

Flue Gas Dew Pt ( $^{\circ}\text{F}$ )	% Excess Air	% $\text{O}_2$ (dry)	% $\text{CO}_2$ (dry)	$\Delta T = 60^{\circ}\text{F}$		$\Delta T = 70^{\circ}\text{F}$		$\Delta T = 80^{\circ}\text{F}$		$\Delta T = 90^{\circ}\text{F}$		$\Delta T = 100^{\circ}\text{F}$		$\Delta T = 110^{\circ}\text{F}$	
				$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing
120.963	0	0	0	92.646	96.353	92.442	95.234	92.237	93.866	92.031	92.191	91.826	91.826	91.62	91.62
120.196	2.285	0.5	15.309	92.622	96.275	92.413	95.133	92.203	93.736	91.994	92.027	91.784	91.784	91.574	91.574
119.410	4.685	1	14.936	92.595	96.193	92.382	95.027	92.168	93.6	91.954	91.954	91.74	91.74	91.526	91.526
118.604	7.207	1.5	14.562	92.568	96.106	92.35	94.915	92.132	93.457	91.913	91.913	91.694	91.694	91.475	91.475
117.778	9.862	2	14.189	92.539	96.015	92.316	94.797	92.093	93.307	91.87	91.87	91.646	91.646	91.422	91.422
116.930	12.661	2.5	13.816	92.508	95.919	92.28	94.673	92.052	93.148	91.824	91.824	91.595	91.595	91.366	91.366
116.059	15.616	3	13.442	92.476	95.818	92.243	94.542	92.009	92.98	91.775	91.775	91.541	91.541	91.307	91.307
115.165	18.739	3.5	13.069	92.442	95.711	92.203	94.404	91.964	92.803	91.724	91.724	91.484	91.484	91.244	91.244
114.245	22.046	4	12.695	92.406	95.597	92.161	94.257	91.916	92.616	91.67	91.67	91.424	91.424	91.178	91.178
113.298	25.553	4.5	12.322	92.368	95.477	92.116	94.102	91.865	92.417	91.613	91.613	91.36	91.36	91.108	91.108
112.323	29.279	5	11.949	92.327	95.349	92.069	93.936	91.81	92.206	91.552	91.552	91.293	91.293	91.033	91.033
111.319	33.246	5.5	11.575	92.284	95.213	92.018	93.761	91.753	91.981	91.487	91.487	91.22	91.22	90.954	90.954
110.282	37.477	6	11.202	92.237	95.068	91.964	93.573	91.691	91.741	91.417	91.417	91.143	91.143	90.869	90.869
109.212	42.001	6.5	10.828	92.188	94.912	91.907	93.373	91.625	91.625	91.343	91.343	91.061	91.061	90.778	90.778
108.106	46.847	7	10.455	92.135	94.746	91.845	93.158	91.555	91.555	91.264	91.264	90.973	90.973	90.681	90.681
106.961	52.052	7.5	10.082	92.078	94.568	91.779	92.927	91.479	91.479	91.179	91.179	90.878	90.878	90.577	90.577
105.775	57.658	8	9.708	92.017	94.375	91.707	92.679	91.397	91.397	91.087	91.087	90.776	90.776	90.465	90.465
104.546	63.712	8.5	9.335	91.951	94.167	91.63	92.41	91.309	91.309	90.988	90.988	90.666	90.666	90.344	90.344
103.268	70.270	9	8.962	91.88	93.942	91.547	92.119	91.214	91.214	90.88	90.88	90.546	90.546	90.212	90.212
101.939	77.399	9.5	8.588	91.802	93.698	91.456	91.803	91.11	91.11	90.763	90.763	90.417	90.417	90.07	90.07
100.555	85.176	10	8.215	91.717	93.431	91.357	91.459	90.997	90.997	90.636	90.636	90.275	90.275	89.914	89.914
99.110	93.694	10.5	7.841	91.624	93.139	91.248	91.248	90.873	90.873	90.497	90.497	90.12	90.12	89.743	89.743
97.600	103.063	11	7.468	91.522	92.817	91.129	91.129	90.736	90.736	90.343	90.343	89.95	89.95	89.556	89.556
96.017	113.419	11.5	7.095	91.409	92.462	90.997	90.997	90.586	90.586	90.173	90.173	89.761	89.761	89.348	89.348
94.354	124.925	12	6.721	91.283	92.067	90.851	90.851	90.418	90.418	89.985	89.985	89.552	89.552	89.118	89.118
92.604	137.785	12.5	6.348	91.143	91.626	90.687	90.687	90.231	90.231	89.774	89.774	89.318	89.318	88.86	88.86
90.755	152.252	13	5.974	90.985	91.129	90.503	90.503	90.02	90.02	89.537	89.537	89.054	89.054	88.571	88.571
88.797	168.649	13.5	5.601	90.806	90.806	90.294	90.294	89.782	89.782	89.269	89.269	88.756	88.756	88.242	88.242
86.714	187.387	14	5.228	90.601	90.601	90.055	90.055	89.509	89.509	88.962	88.962	88.415	88.415	87.867	87.867
84.491	209.009	14.5	4.854	90.365	90.365	89.78	89.78	89.194	89.194	88.608	88.608	88.021	88.021	87.434	87.434
82.104	234.234	15	4.481	90.09	90.09	89.459	89.459	88.827	88.827	88.195	88.195	87.562	87.562	86.929	86.929



**Table A4.11b. #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [T<sub>(ambient)</sub> = 30°F]; [125°F ≤ ΔT ≤ 600°F.]**

**Ultimate Analysis:** Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%  
**P<sub>(ambient)</sub> = 14.696 psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
120.963	0	0	0	91.31	90.793	90.274	89.753	89.23	88.705	87.649	86.585	85.513	84.432	83.343	81.138
120.196	2.285	0.5	15.309	91.258	90.731	90.201	89.67	89.136	88.601	87.524	86.439	85.345	84.242	83.131	80.883
119.41	4.685	1	14.936	91.204	90.665	90.124	89.582	89.038	88.491	87.392	86.284	85.168	84.043	82.909	80.616
118.604	7.207	1.5	14.562	91.146	90.596	90.044	89.49	88.934	88.376	87.253	86.122	84.982	83.834	82.676	80.334
117.778	9.862	2	14.189	91.086	90.523	89.959	89.393	88.825	88.254	87.107	85.952	84.787	83.613	82.431	80.038
116.93	12.661	2.5	13.816	91.022	90.447	89.87	89.291	88.71	88.127	86.954	85.772	84.581	83.381	82.172	79.725
116.059	15.616	3	13.442	90.955	90.366	89.776	89.183	88.588	87.992	86.791	85.582	84.363	83.136	81.899	79.396
115.165	18.739	3.5	13.069	90.884	90.281	89.676	89.069	88.46	87.849	86.62	85.381	84.134	82.876	81.61	79.047
114.245	22.046	4	12.695	90.808	90.19	89.57	88.948	88.324	87.698	86.438	85.169	83.89	82.602	81.304	78.678
113.298	25.553	4.5	12.322	90.728	90.095	89.458	88.82	88.18	87.537	86.245	84.943	83.632	82.311	80.979	78.287
112.323	29.279	5	11.949	90.644	89.993	89.34	88.684	88.027	87.367	86.04	84.704	83.358	82.001	80.635	77.871
111.319	33.246	5.5	11.575	90.553	89.884	89.213	88.54	87.864	87.186	85.822	84.449	83.066	81.672	80.268	77.429
110.282	37.477	6	11.202	90.457	89.769	89.078	88.385	87.69	86.992	85.59	84.177	82.754	81.321	79.877	76.956
109.212	42.001	6.5	10.828	90.354	89.645	88.934	88.22	87.504	86.786	85.341	83.886	82.421	80.945	79.458	76.452
108.106	46.847	7	10.455	90.244	89.512	88.779	88.043	87.305	86.564	85.075	83.575	82.064	80.543	79.01	75.911
106.961	52.052	7.5	10.082	90.125	89.37	88.613	87.853	87.091	86.326	84.789	83.241	81.681	80.111	78.529	75.33
105.775	57.658	8	9.708	89.998	89.217	88.434	87.648	86.86	86.07	84.481	82.88	81.269	79.645	78.01	74.705
104.546	63.712	8.5	9.335	89.86	89.051	88.241	87.427	86.612	85.793	84.148	82.491	80.823	79.143	77.45	74.029
103.268	70.27	9	8.962	89.71	88.872	88.031	87.188	86.342	85.493	83.787	82.07	80.34	78.598	76.844	73.297
101.939	77.399	9.5	8.588	89.548	88.677	87.804	86.928	86.049	85.168	83.396	81.612	79.815	78.006	76.185	72.502
100.555	85.176	10	8.215	89.371	88.465	87.556	86.644	85.729	84.812	82.968	81.112	79.243	77.361	75.465	71.634
99.11	93.694	10.5	7.841	89.177	88.232	87.284	86.333	85.379	84.423	82.5	80.565	78.616	76.654	74.678	70.684
97.6	103.063	11	7.468	88.964	87.976	86.985	85.991	84.994	83.994	81.985	79.962	77.926	75.876	73.811	69.638
96.017	113.419	11.5	7.095	88.728	87.693	86.654	85.613	84.569	83.521	81.416	79.297	77.164	75.016	72.853	68.483
94.354	124.925	12	6.721	88.466	87.378	86.287	85.193	84.096	82.995	80.784	78.558	76.317	74.061	71.789	67.199
92.604	137.785	12.5	6.348	88.174	87.027	85.877	84.724	83.567	82.407	80.077	77.731	75.37	72.993	70.6	65.764
90.755	152.252	13	5.974	87.844	86.631	85.415	84.196	82.973	81.746	79.282	76.802	74.305	71.792	69.262	64.15
88.797	168.649	13.5	5.601	87.471	86.183	84.892	83.597	82.299	80.997	78.381	75.748	73.098	70.431	67.745	62.32
86.714	187.387	14	5.228	87.044	85.671	84.294	82.913	81.529	80.14	77.351	74.544	71.719	68.875	66.012	60.229
84.491	209.009	14.5	4.854	86.552	85.08	83.604	82.124	80.64	79.152	76.162	73.154	70.127	67.08	64.013	57.817
82.104	234.234	15	4.481	85.978	84.39	82.799	81.203	79.603	77.999	74.776	71.533	68.27	64.986	61.68	55.002

**Table A4.12a. #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [ $T_{\text{ambient}} = 40^{\circ}\text{F}$ ]; [ $50^{\circ}\text{F} \leq \Delta T \leq 100^{\circ}\text{F}$ ].**

**Ultimate Analysis:** Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%

$P_{\text{ambient}} = 14.696$  psia

Flue Gas Dew Pt ( $^{\circ}\text{F}$ )	% Excess Air	% $\text{O}_2$ (dry)	% $\text{CO}_2$ (dry)	$\Delta T = 50^{\circ}\text{F}$		$\Delta T = 60^{\circ}\text{F}$		$\Delta T = 70^{\circ}\text{F}$		$\Delta T = 80^{\circ}\text{F}$		$\Delta T = 90^{\circ}\text{F}$		$\Delta T = 100^{\circ}\text{F}$	
				$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing
120.963	0	0	0	92.823	96.53	92.619	95.411	92.413	94.043	92.208	92.368	92.002	92.002	91.796	91.796
120.196	2.285	0.5	15.309	92.803	96.456	92.594	95.314	92.384	93.917	92.175	92.208	91.965	91.965	91.755	91.755
119.410	4.685	1	14.936	92.781	96.378	92.567	95.212	92.354	93.786	92.14	92.14	91.926	91.926	91.711	91.711
118.604	7.207	1.5	14.562	92.758	96.296	92.54	95.105	92.322	93.647	92.103	92.103	91.884	91.884	91.665	91.665
117.778	9.862	2	14.189	92.734	96.21	92.511	94.992	92.288	93.501	92.064	92.064	91.841	91.841	91.617	91.617
116.930	12.661	2.5	13.816	92.708	96.119	92.48	94.873	92.252	93.348	92.024	92.024	91.795	91.795	91.566	91.566
116.059	15.616	3	13.442	92.681	96.023	92.448	94.747	92.215	93.186	91.981	91.981	91.747	91.747	91.512	91.512
115.165	18.739	3.5	13.069	92.653	95.921	92.414	94.615	92.175	93.014	91.935	91.935	91.695	91.695	91.455	91.455
114.245	22.046	4	12.695	92.623	95.814	92.378	94.474	92.133	92.833	91.887	91.887	91.641	91.641	91.395	91.395
113.298	25.553	4.5	12.322	92.591	95.7	92.34	94.325	92.088	92.64	91.836	91.836	91.584	91.584	91.331	91.331
112.323	29.279	5	11.949	92.557	95.579	92.299	94.167	92.04	92.436	91.782	91.782	91.523	91.523	91.263	91.263
111.319	33.246	5.5	11.575	92.521	95.45	92.256	93.998	91.99	92.218	91.724	91.724	91.458	91.458	91.191	91.191
110.282	37.477	6	11.202	92.482	95.313	92.209	93.818	91.936	91.986	91.662	91.662	91.388	91.388	91.114	91.114
109.212	42.001	6.5	10.828	92.441	95.166	92.16	93.626	91.878	91.878	91.597	91.597	91.314	91.314	91.032	91.032
108.106	46.847	7	10.455	92.397	95.008	92.107	93.42	91.817	91.817	91.526	91.526	91.235	91.235	90.943	90.943
106.961	52.052	7.5	10.082	92.35	94.839	92.05	93.199	91.75	91.75	91.45	91.45	91.15	91.15	90.849	90.849
105.775	57.658	8	9.708	92.299	94.657	91.989	92.96	91.679	91.679	91.369	91.369	91.058	91.058	90.747	90.747
104.546	63.712	8.5	9.335	92.244	94.46	91.923	92.703	91.602	91.602	91.28	91.28	90.959	90.959	90.636	90.636
103.268	70.270	9	8.962	92.184	94.247	91.851	92.424	91.518	91.518	91.185	91.185	90.851	90.851	90.517	90.517
101.939	77.399	9.5	8.588	92.119	94.015	91.774	92.121	91.428	91.428	91.081	91.081	90.734	90.734	90.387	90.387
100.555	85.176	10	8.215	92.049	93.763	91.689	91.791	91.328	91.328	90.968	90.968	90.607	90.607	90.246	90.246
99.110	93.694	10.5	7.841	91.971	93.486	91.596	91.596	91.22	91.22	90.844	90.844	90.467	90.467	90.091	90.091
97.600	103.063	11	7.468	91.886	93.182	91.493	91.493	91.101	91.101	90.707	90.707	90.314	90.314	89.92	89.92
96.017	113.419	11.5	7.095	91.792	92.845	91.38	91.38	90.969	90.969	90.557	90.557	90.144	90.144	89.731	89.731
94.354	124.925	12	6.721	91.687	92.471	91.255	91.255	90.822	90.822	90.389	90.389	89.956	89.956	89.522	89.522
92.604	137.785	12.5	6.348	91.57	92.053	91.114	91.114	90.658	90.658	90.202	90.202	89.745	89.745	89.288	89.288
90.755	152.252	13	5.974	91.438	91.583	90.956	90.956	90.474	90.474	89.991	89.991	89.508	89.508	89.024	89.024
88.797	168.649	13.5	5.601	91.289	91.289	90.777	90.777	90.265	90.265	89.752	89.752	89.239	89.239	88.726	88.726
86.714	187.387	14	5.228	91.119	91.119	90.573	90.573	90.026	90.026	89.48	89.48	88.932	88.932	88.385	88.385
84.491	209.009	14.5	4.854	90.922	90.922	90.337	90.337	89.751	89.751	89.165	89.165	88.578	88.578	87.991	87.991
82.104	234.234	15	4.481	90.693	90.693	90.061	90.061	89.43	89.43	88.798	88.798	88.165	88.165	87.532	87.532

**Table A4.12b. #2 Fuel Oil; [HHV = 131,476 Btu/gal]; [ $T_{(ambient)} = 40^{\circ}\text{F}$ ]; [ $125^{\circ}\text{F} \leq \Delta T \leq 600^{\circ}\text{F}$ ].**

**Ultimate Analysis: Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%**  
 $P_{(ambient)} = 14.696$  psia

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	$\Delta T = 125^{\circ}\text{F}$	$\Delta T = 150^{\circ}\text{F}$	$\Delta T = 175^{\circ}\text{F}$	$\Delta T = 200^{\circ}\text{F}$	$\Delta T = 225^{\circ}\text{F}$	$\Delta T = 250^{\circ}\text{F}$	$\Delta T = 300^{\circ}\text{F}$	$\Delta T = 350^{\circ}\text{F}$	$\Delta T = 400^{\circ}\text{F}$	$\Delta T = 450^{\circ}\text{F}$	$\Delta T = 500^{\circ}\text{F}$	$\Delta T = 600^{\circ}\text{F}$
				$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.
120.963	0	0	0	91.28	90.762	90.243	89.721	89.197	88.672	87.614	86.548	85.474	84.392	83.301	81.093
120.196	2.285	0.5	15.309	91.228	90.7	90.17	89.638	89.103	88.567	87.489	86.402	85.306	84.202	83.089	80.838
119.41	4.685	1	14.936	91.174	90.634	90.093	89.55	89.005	88.457	87.357	86.247	85.129	84.003	82.867	80.57
118.604	7.207	1.5	14.562	91.116	90.565	90.013	89.458	88.901	88.342	87.218	86.085	84.943	83.793	82.634	80.288
117.778	9.862	2	14.189	91.056	90.493	89.928	89.361	88.792	88.221	87.072	85.914	84.748	83.572	82.388	79.991
116.93	12.661	2.5	13.816	90.992	90.416	89.838	89.259	88.677	88.093	86.918	85.734	84.542	83.34	82.129	79.679
116.059	15.616	3	13.442	90.925	90.335	89.744	89.151	88.555	87.957	86.755	85.544	84.324	83.094	81.855	79.349
115.165	18.739	3.5	13.069	90.854	90.25	89.644	89.037	88.427	87.815	86.584	85.343	84.094	82.835	81.566	79
114.245	22.046	4	12.695	90.778	90.16	89.539	88.916	88.291	87.663	86.402	85.131	83.85	82.56	81.26	78.631
113.298	25.553	4.5	12.322	90.698	90.064	89.427	88.788	88.146	87.503	86.209	84.905	83.592	82.269	80.935	78.239
112.323	29.279	5	11.949	90.614	89.962	89.308	88.652	87.993	87.333	86.004	84.666	83.317	81.959	80.59	77.823
111.319	33.246	5.5	11.575	90.523	89.853	89.181	88.507	87.83	87.151	85.786	84.41	83.025	81.629	80.223	77.38
110.282	37.477	6	11.202	90.427	89.738	89.046	88.352	87.656	86.958	85.553	84.138	82.713	81.278	79.832	76.907
109.212	42.001	6.5	10.828	90.324	89.614	88.902	88.187	87.47	86.751	85.304	83.847	82.38	80.902	79.413	76.402
108.106	46.847	7	10.455	90.214	89.481	88.747	88.01	87.271	86.529	85.038	83.536	82.023	80.499	78.964	75.861
106.961	52.052	7.5	10.082	90.095	89.339	88.581	87.82	87.057	86.291	84.751	83.201	81.64	80.067	78.482	75.279
105.775	57.658	8	9.708	89.967	89.186	88.402	87.615	86.826	86.035	84.443	82.841	81.227	79.601	77.964	74.653
104.546	63.712	8.5	9.335	89.829	89.02	88.208	87.394	86.577	85.758	84.11	82.451	80.781	79.098	77.403	73.977
103.268	70.27	9	8.962	89.68	88.841	87.999	87.155	86.308	85.458	83.75	82.029	80.297	78.553	76.796	73.245
101.939	77.399	9.5	8.588	89.518	88.646	87.771	86.894	86.014	85.132	83.357	81.571	79.772	77.961	76.136	72.448
100.555	85.176	10	8.215	89.341	88.433	87.523	86.61	85.695	84.776	82.93	81.071	79.199	77.314	75.416	71.58
99.11	93.694	10.5	7.841	89.147	88.2	87.251	86.299	85.344	84.386	82.461	80.523	78.572	76.607	74.628	70.629
97.6	103.063	11	7.468	88.933	87.944	86.952	85.957	84.959	83.958	81.946	79.921	77.881	75.828	73.761	69.582
96.017	113.419	11.5	7.095	88.698	87.661	86.621	85.579	84.533	83.484	81.376	79.255	77.119	74.968	72.802	68.426
94.354	124.925	12	6.721	88.435	87.346	86.254	85.159	84.06	82.958	80.744	78.515	76.271	74.012	71.737	67.14
92.604	137.785	12.5	6.348	88.143	86.995	85.843	84.689	83.531	82.37	80.036	77.688	75.323	72.943	70.547	65.704
90.755	152.252	13	5.974	87.813	86.599	85.382	84.161	82.936	81.708	79.241	76.757	74.258	71.741	69.207	64.088
88.797	168.649	13.5	5.601	87.44	86.151	84.858	83.562	82.262	80.958	78.339	75.703	73.05	70.379	67.69	62.257
86.714	187.387	14	5.228	87.013	85.638	84.26	82.878	81.491	80.101	77.308	74.498	71.669	68.822	65.955	60.164
84.491	209.009	14.5	4.854	86.521	85.047	83.569	82.088	80.602	79.112	76.119	73.107	70.076	67.025	63.954	57.749
82.104	234.234	15	4.481	85.946	84.357	82.764	81.167	79.565	77.959	74.732	71.485	68.218	64.929	61.619	54.932

**Table A4.13a. #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [ $T_{\text{ambient}} = 20^{\circ}\text{F}$ ]; [ $70^{\circ}\text{F} \leq \Delta T \leq 120^{\circ}\text{F}$ ].**

**Ultimate Analysis:** Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%

$P_{\text{ambient}} = 14.696$  psia

Flue Gas Dew Pt ( $^{\circ}\text{F}$ )	% Excess Air	% $\text{O}_2$ (dry)	% $\text{CO}_2$ (dry)	$\Delta T = 70^{\circ}\text{F}$		$\Delta T = 80^{\circ}\text{F}$		$\Delta T = 90^{\circ}\text{F}$		$\Delta T = 100^{\circ}\text{F}$		$\Delta T = 110^{\circ}\text{F}$		$\Delta T = 120^{\circ}\text{F}$	
				$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing
120.963	0	0	0	92.693	96.29	92.495	95.204	92.296	93.876	92.096	92.252	91.897	91.897	91.697	91.697
120.196	2.285	0.5	15.309	92.665	96.21	92.462	95.102	92.259	93.747	92.056	92.088	91.852	91.852	91.648	91.648
119.410	4.685	1	14.936	92.635	96.126	92.428	94.995	92.221	93.61	92.014	92.014	91.806	91.806	91.598	91.598
118.604	7.207	1.5	14.562	92.604	96.038	92.393	94.882	92.181	93.467	91.969	91.969	91.757	91.757	91.544	91.544
117.778	9.862	2	14.189	92.571	95.945	92.355	94.763	92.139	93.316	91.922	91.922	91.705	91.705	91.488	91.488
116.930	12.661	2.5	13.816	92.537	95.846	92.316	94.637	92.094	93.157	91.873	91.873	91.651	91.651	91.429	91.429
116.059	15.616	3	13.442	92.5	95.743	92.274	94.505	92.047	92.99	91.821	91.821	91.593	91.593	91.366	91.366
115.165	18.739	3.5	13.069	92.462	95.633	92.23	94.365	91.998	92.812	91.765	91.765	91.533	91.533	91.3	91.3
114.245	22.046	4	12.695	92.421	95.517	92.183	94.217	91.945	92.625	91.707	91.707	91.468	91.468	91.23	91.23
113.298	25.553	4.5	12.322	92.378	95.394	92.134	94.06	91.89	92.425	91.645	91.645	91.4	91.4	91.155	91.155
112.323	29.279	5	11.949	92.332	95.264	92.081	93.893	91.83	92.214	91.579	91.579	91.328	91.328	91.076	91.076
111.319	33.246	5.5	11.575	92.283	95.125	92.025	93.716	91.767	91.988	91.509	91.509	91.251	91.251	90.992	90.992
110.282	37.477	6	11.202	92.23	94.976	91.965	93.526	91.7	91.748	91.434	91.434	91.169	91.169	90.902	90.902
109.212	42.001	6.5	10.828	92.174	94.818	91.901	93.324	91.628	91.628	91.355	91.355	91.081	91.081	90.807	90.807
108.106	46.847	7	10.455	92.114	94.648	91.833	93.107	91.551	91.551	91.269	91.269	90.987	90.987	90.704	90.704
106.961	52.052	7.5	10.082	92.05	94.465	91.759	92.874	91.468	91.468	91.177	91.177	90.886	90.886	90.594	90.594
105.775	57.658	8	9.708	91.981	94.269	91.68	92.623	91.379	91.379	91.078	91.078	90.777	90.777	90.475	90.475
104.546	63.712	8.5	9.335	91.906	94.057	91.595	92.352	91.283	91.283	90.971	90.971	90.659	90.659	90.346	90.346
103.268	70.270	9	8.962	91.825	93.827	91.502	92.058	91.179	91.179	90.855	90.855	90.532	90.532	90.207	90.207
101.939	77.399	9.5	8.588	91.737	93.577	91.402	91.739	91.066	91.066	90.73	90.73	90.393	90.393	90.056	90.056
100.555	85.176	10	8.215	91.641	93.304	91.292	91.39	90.942	90.942	90.592	90.592	90.242	90.242	89.891	89.891
99.110	93.694	10.5	7.841	91.536	93.006	91.171	91.171	90.807	90.807	90.442	90.442	90.077	90.077	89.711	89.711
97.600	103.063	11	7.468	91.42	92.677	91.039	91.039	90.658	90.658	90.276	90.276	89.895	89.895	89.512	89.512
96.017	113.419	11.5	7.095	91.292	92.314	90.893	90.893	90.493	90.493	90.094	90.094	89.693	89.693	89.293	89.293
94.354	124.925	12	6.721	91.15	91.911	90.73	90.73	90.311	90.311	89.89	89.89	89.47	89.47	89.049	89.049
92.604	137.785	12.5	6.348	90.991	91.46	90.549	90.549	90.106	90.106	89.663	89.663	89.22	89.22	88.776	88.776
90.755	152.252	13	5.974	90.812	90.953	90.344	90.344	89.876	89.876	89.408	89.408	88.939	88.939	88.47	88.47
88.797	168.649	13.5	5.601	90.61	90.61	90.113	90.113	89.616	89.616	89.118	89.118	88.62	88.62	88.122	88.122
86.714	187.387	14	5.228	90.378	90.378	89.848	89.848	89.318	89.318	88.787	88.787	88.256	88.256	87.725	87.725
84.491	209.009	14.5	4.854	90.111	90.111	89.543	89.543	88.975	88.975	88.406	88.406	87.836	87.836	87.267	87.267
82.104	234.234	15	4.481	89.799	89.799	89.187	89.187	88.574	88.574	87.96	87.96	87.346	87.346	86.732	86.732

**Table A4.13b. #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis: Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%**  
**P<sub>(ambient)</sub> = 14.696 psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
120.963	0	0	0	91.597	91.096	90.593	90.088	89.582	89.073	88.05	87.019	85.98	84.933	83.878	81.742
120.196	2.285	0.5	15.309	91.546	91.035	90.522	90.007	89.49	88.972	87.928	86.877	85.817	84.749	83.673	81.495
119.41	4.685	1	14.936	91.493	90.972	90.448	89.922	89.395	88.865	87.8	86.727	85.646	84.556	83.458	81.235
118.604	7.207	1.5	14.562	91.438	90.905	90.37	89.833	89.294	88.754	87.666	86.57	85.466	84.353	83.232	80.962
117.778	9.862	2	14.189	91.379	90.834	90.288	89.739	89.188	88.636	87.525	86.405	85.276	84.139	82.993	80.675
116.93	12.661	2.5	13.816	91.317	90.76	90.201	89.64	89.077	88.512	87.375	86.23	85.077	83.914	82.743	80.372
116.059	15.616	3	13.442	91.252	90.682	90.11	89.535	88.959	88.381	87.218	86.046	84.866	83.676	82.478	80.053
115.165	18.739	3.5	13.069	91.183	90.599	90.013	89.425	88.835	88.242	87.051	85.852	84.643	83.425	82.198	79.715
114.245	22.046	4	12.695	91.11	90.511	89.911	89.308	88.703	88.096	86.875	85.646	84.407	83.159	81.901	79.357
113.298	25.553	4.5	12.322	91.033	90.418	89.802	89.184	88.563	87.94	86.688	85.427	84.156	82.876	81.587	78.978
112.323	29.279	5	11.949	90.95	90.319	89.687	89.052	88.415	87.775	86.49	85.195	83.891	82.576	81.252	78.575
111.319	33.246	5.5	11.575	90.863	90.214	89.564	88.911	88.256	87.599	86.278	84.948	83.607	82.257	80.897	78.146
110.282	37.477	6	11.202	90.769	90.102	89.433	88.761	88.088	87.412	86.053	84.684	83.305	81.917	80.517	77.688
109.212	42.001	6.5	10.828	90.669	89.982	89.293	88.601	87.907	87.211	85.812	84.402	82.983	81.552	80.112	77.199
108.106	46.847	7	10.455	90.562	89.854	89.143	88.43	87.714	87.006	85.553	84.1	82.637	81.162	79.677	76.675
106.961	52.052	7.5	10.082	90.447	89.716	88.982	88.245	87.507	86.766	85.276	83.776	82.265	80.743	79.211	76.111
105.775	57.658	8	9.708	90.324	89.567	88.808	88.047	87.283	86.517	84.977	83.427	81.865	80.292	78.708	75.505
104.546	63.712	8.5	9.335	90.19	89.407	88.621	87.833	87.042	86.249	84.655	83.049	81.433	79.805	78.165	74.85
103.268	70.27	9	8.962	90.045	89.233	88.418	87.601	86.781	85.958	84.305	82.641	80.965	79.277	77.577	74.141
101.939	77.399	9.5	8.588	89.888	89.044	88.197	87.348	86.497	85.642	83.925	82.197	80.456	78.703	76.938	73.37
100.555	85.176	10	8.215	89.716	88.837	87.956	87.073	86.187	85.298	83.511	81.712	79.901	78.077	76.241	72.528
99.11	93.694	10.5	7.841	89.528	88.612	87.693	86.771	85.847	84.92	83.057	81.181	79.293	77.392	75.477	71.607
97.6	103.063	11	7.468	89.321	88.363	87.403	86.44	85.474	84.505	82.557	80.597	78.624	76.637	74.637	70.594
96.017	113.419	11.5	7.095	89.092	88.089	87.082	86.073	85.061	84.046	82.006	79.952	77.885	75.804	73.708	69.473
94.354	124.925	12	6.721	88.838	87.784	86.726	85.666	84.602	83.536	81.392	79.235	77.064	74.878	72.677	68.229
92.604	137.785	12.5	6.348	88.554	87.443	86.328	85.21	84.09	82.966	80.707	78.434	76.146	73.843	71.523	66.838
90.755	152.252	13	5.974	88.235	87.059	85.88	84.698	83.513	82.324	79.936	77.533	75.113	72.678	70.226	65.273
88.797	168.649	13.5	5.601	87.873	86.624	85.373	84.118	82.86	81.598	79.062	76.511	73.943	71.358	68.756	63.499
86.714	187.387	14	5.228	87.459	86.128	84.793	83.455	82.113	80.767	78.063	75.343	72.606	69.85	67.076	61.472
84.491	209.009	14.5	4.854	86.982	85.554	84.124	82.689	81.251	79.809	76.911	73.996	71.062	68.11	65.137	59.133
82.104	234.234	15	4.481	86.425	84.885	83.343	81.796	80.245	78.69	75.567	72.424	69.262	66.079	62.875	56.404

**Table A4.14a. #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [ $T_{\text{ambient}} = 30^{\circ}\text{F}$ ]; [ $60^{\circ}\text{F} \leq \Delta T \leq 110^{\circ}\text{F}$ ].**

**Ultimate Analysis:** Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%

$P_{\text{ambient}} = 14.696$  psia

Flue Gas Dew Pt ( $^{\circ}\text{F}$ )	% Excess Air	% $\text{O}_2$ (dry)	% $\text{CO}_2$ (dry)	$\Delta T = 60^{\circ}\text{F}$		$\Delta T = 70^{\circ}\text{F}$		$\Delta T = 80^{\circ}\text{F}$		$\Delta T = 90^{\circ}\text{F}$		$\Delta T = 100^{\circ}\text{F}$		$\Delta T = 110^{\circ}\text{F}$	
				$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing
120.963	0	0	0	92.865	96.462	92.666	95.376	92.467	94.048	92.268	92.423	92.068	92.068	91.868	91.868
120.196	2.285	0.5	15.309	92.841	96.386	92.638	95.277	92.435	93.922	92.231	92.263	92.028	92.028	91.824	91.824
119.410	4.685	1	14.936	92.815	96.306	92.608	95.174	92.401	93.79	92.193	92.193	91.985	91.985	91.777	91.777
118.604	7.207	1.5	14.562	92.788	96.222	92.577	95.066	92.365	93.651	92.153	92.153	91.941	91.941	91.728	91.728
117.778	9.862	2	14.189	92.76	96.133	92.544	94.951	92.328	93.505	92.111	92.111	91.894	91.894	91.677	91.677
116.930	12.661	2.5	13.816	92.731	96.04	92.51	94.831	92.288	93.351	92.066	92.066	91.845	91.845	91.622	91.622
116.059	15.616	3	13.442	92.699	95.942	92.473	94.704	92.246	93.189	92.02	92.02	91.792	91.792	91.565	91.565
115.165	18.739	3.5	13.069	92.666	95.838	92.434	94.57	92.202	93.017	91.97	91.97	91.737	91.737	91.504	91.504
114.245	22.046	4	12.695	92.631	95.728	92.394	94.427	92.156	92.835	91.917	91.917	91.679	91.679	91.44	91.44
113.298	25.553	4.5	12.322	92.594	95.611	92.35	94.277	92.106	92.642	91.862	91.862	91.617	91.617	91.372	91.372
112.323	29.279	5	11.949	92.555	95.487	92.304	94.116	92.053	92.437	91.802	91.802	91.551	91.551	91.299	91.299
111.319	33.246	5.5	11.575	92.513	95.355	92.255	93.946	91.997	92.219	91.739	91.739	91.481	91.481	91.222	91.222
110.282	37.477	6	11.202	92.468	95.214	92.203	93.764	91.938	91.986	91.672	91.672	91.406	91.406	91.14	91.14
109.212	42.001	6.5	10.828	92.42	95.063	92.147	93.569	91.874	91.874	91.6	91.6	91.326	91.326	91.052	91.052
108.106	46.847	7	10.455	92.369	94.902	92.087	93.361	91.805	91.805	91.523	91.523	91.241	91.241	90.958	90.958
106.961	52.052	7.5	10.082	92.313	94.729	92.023	93.137	91.732	91.732	91.44	91.44	91.149	91.149	90.857	90.857
105.775	57.658	8	9.708	92.254	94.542	91.953	92.896	91.653	91.653	91.351	91.351	91.05	91.05	90.748	90.748
104.546	63.712	8.5	9.335	92.19	94.341	91.879	92.635	91.567	91.567	91.255	91.255	90.943	90.943	90.63	90.63
103.268	70.270	9	8.962	92.121	94.122	91.798	92.353	91.474	91.474	91.151	91.151	90.827	90.827	90.503	90.503
101.939	77.399	9.5	8.588	92.045	93.885	91.71	92.047	91.374	91.374	91.038	91.038	90.701	90.701	90.364	90.364
100.555	85.176	10	8.215	91.963	93.626	91.613	91.712	91.264	91.264	90.914	90.914	90.564	90.564	90.213	90.213
99.110	93.694	10.5	7.841	91.872	93.342	91.508	91.508	91.144	91.144	90.779	90.779	90.413	90.413	90.048	90.048
97.600	103.063	11	7.468	91.773	93.03	91.392	91.392	91.011	91.011	90.63	90.63	90.248	90.248	89.866	89.866
96.017	113.419	11.5	7.095	91.664	92.686	91.264	91.264	90.865	90.865	90.465	90.465	90.065	90.065	89.664	89.664
94.354	124.925	12	6.721	91.542	92.303	91.122	91.122	90.702	90.702	90.282	90.282	89.862	89.862	89.441	89.441
92.604	137.785	12.5	6.348	91.405	91.874	90.963	90.963	90.521	90.521	90.078	90.078	89.635	89.635	89.191	89.191
90.755	152.252	13	5.974	91.252	91.393	90.785	90.785	90.316	90.316	89.848	89.848	89.379	89.379	88.91	88.91
88.797	168.649	13.5	5.601	91.079	91.079	90.582	90.582	90.085	90.085	89.587	89.587	89.089	89.089	88.591	88.591
86.714	187.387	14	5.228	90.88	90.88	90.35	90.35	89.82	89.82	89.29	89.29	88.759	88.759	88.227	88.227
84.491	209.009	14.5	4.854	90.651	90.651	90.083	90.083	89.515	89.515	88.946	88.946	88.377	88.377	87.807	87.807
82.104	234.234	15	4.481	90.384	90.384	89.771	89.771	89.158	89.158	88.545	88.545	87.931	87.931	87.317	87.317

**Table A4.14b. #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [T<sub>(ambient)</sub> = 30°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%  
**P<sub>(ambient)</sub> = 14.696 psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
120.963	0	0	0	91.568	91.066	90.563	90.057	89.55	89.04	88.016	86.984	85.943	84.894	83.837	81.698
120.196	2.285	0.5	15.309	91.518	91.006	90.492	89.976	89.459	88.939	87.894	86.841	85.78	84.71	83.632	81.451
119.41	4.685	1	14.936	91.465	90.942	90.418	89.891	89.363	88.833	87.766	86.691	85.608	84.517	83.417	81.191
118.604	7.207	1.5	14.562	91.409	90.875	90.339	89.802	89.262	88.721	87.632	86.534	85.428	84.314	83.19	80.918
117.778	9.862	2	14.189	91.35	90.805	90.257	89.708	89.156	88.603	87.49	86.369	85.239	84.1	82.952	80.63
116.93	12.661	2.5	13.816	91.288	90.73	90.171	89.609	89.045	88.479	87.341	86.194	85.039	83.874	82.701	80.327
116.059	15.616	3	13.442	91.223	90.652	90.079	89.504	88.927	88.348	87.183	86.01	84.828	83.636	82.436	80.007
115.165	18.739	3.5	13.069	91.154	90.569	89.982	89.393	88.802	88.209	87.017	85.815	84.604	83.385	82.156	79.669
114.245	22.046	4	12.695	91.081	90.482	89.88	89.276	88.671	88.063	86.84	85.609	84.368	83.118	81.859	79.311
113.298	25.553	4.5	12.322	91.004	90.389	89.771	89.152	88.531	87.907	86.653	85.39	84.118	82.836	81.544	78.931
112.323	29.279	5	11.949	90.921	90.29	89.656	89.02	88.382	87.742	86.455	85.158	83.852	82.536	81.21	78.528
111.319	33.246	5.5	11.575	90.834	90.184	89.533	88.88	88.224	87.566	86.243	84.911	83.568	82.216	80.854	78.099
110.282	37.477	6	11.202	90.74	90.072	89.402	88.73	88.055	87.378	86.017	84.647	83.266	81.875	80.474	77.64
109.212	42.001	6.5	10.828	90.64	89.952	89.262	88.57	87.875	87.178	85.776	84.365	82.943	81.511	80.068	77.151
108.106	46.847	7	10.455	90.533	89.824	89.112	88.398	87.682	86.963	85.518	84.062	82.597	81.12	79.633	76.626
106.961	52.052	7.5	10.082	90.418	89.686	88.951	88.214	87.474	86.732	85.24	83.738	82.225	80.701	79.166	76.062
105.775	57.658	8	9.708	90.294	89.537	88.777	88.015	87.25	86.483	84.941	83.388	81.825	80.249	78.663	75.455
104.546	63.712	8.5	9.335	90.161	89.376	88.59	87.801	87.009	86.215	84.618	83.011	81.392	79.762	78.12	74.8
103.268	70.27	9	8.962	90.016	89.202	88.387	87.568	86.747	85.924	84.269	82.602	80.924	79.233	77.531	74.09
101.939	77.399	9.5	8.588	89.858	89.013	88.166	87.316	86.463	85.608	83.888	82.157	80.414	78.659	76.891	73.318
100.555	85.176	10	8.215	89.687	88.807	87.925	87.04	86.153	85.263	83.474	81.673	79.859	78.033	76.193	72.476
99.11	93.694	10.5	7.841	89.498	88.581	87.661	86.739	85.813	84.885	83.019	81.141	79.251	77.346	75.429	71.554
97.6	103.063	11	7.468	89.292	88.333	87.371	86.407	85.44	84.47	82.52	80.557	78.581	76.592	74.588	70.539
96.017	113.419	11.5	7.095	89.063	88.058	87.051	86.04	85.027	84.01	81.968	79.911	77.842	75.757	73.659	69.418
94.354	124.925	12	6.721	88.809	87.753	86.694	85.633	84.568	83.5	81.354	79.194	77.02	74.831	72.626	68.172
92.604	137.785	12.5	6.348	88.525	87.412	86.296	85.177	84.055	82.93	80.668	78.392	76.101	73.795	71.472	66.78
90.755	152.252	13	5.974	88.205	87.028	85.848	84.665	83.478	82.288	79.897	77.49	75.068	72.629	70.174	65.214
88.797	168.649	13.5	5.601	87.843	86.593	85.34	84.084	82.824	81.561	79.022	76.468	73.897	71.308	68.703	63.438
86.714	187.387	14	5.228	87.429	86.096	84.76	83.42	82.077	80.73	78.023	75.299	72.558	69.799	67.021	61.41
84.491	209.009	14.5	4.854	86.951	85.523	84.09	82.655	81.215	79.771	76.87	73.951	71.014	68.057	65.081	59.069
82.104	234.234	15	4.481	86.394	84.854	83.309	81.761	80.209	78.652	75.525	72.378	69.212	66.025	62.817	56.337

**Table A4.15a. #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [T(ambient) = 40°F]; [50°F ≤ ΔT ≤ 100°F].**

**Ultimate Analysis: Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%**

**P<sub>(ambient)</sub> = 14.696 psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 50°F		ΔT = 60°F		ΔT = 70°F		ΔT = 80°F		ΔT = 90°F		ΔT = 100°F	
				η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing	η (%) Non-Cond.	η (%) Condensing
120.963	0	0	0	93.036	96.633	92.838	95.547	92.639	94.22	92.439	92.595	92.24	92.24	92.04	92.04
120.196	2.285	0.5	15.309	93.016	96.561	92.813	95.453	92.61	94.098	92.407	92.439	92.203	92.203	92	92
119.410	4.685	1	14.936	92.995	96.486	92.788	95.354	92.581	93.97	92.373	92.373	92.165	92.165	91.957	91.957
118.604	7.207	1.5	14.562	92.973	96.406	92.761	95.25	92.55	93.836	92.337	92.337	92.125	92.125	91.913	91.913
117.778	9.862	2	14.189	92.949	96.322	92.733	95.141	92.517	93.694	92.3	92.3	92.083	92.083	91.866	91.866
116.930	12.661	2.5	13.816	92.925	96.234	92.703	95.025	92.482	93.545	92.26	92.26	92.038	92.038	91.816	91.816
116.059	15.616	3	13.442	92.899	96.141	92.672	94.903	92.446	93.388	92.219	92.219	91.992	91.992	91.764	91.764
115.165	18.739	3.5	13.069	92.871	96.043	92.639	94.774	92.407	93.222	92.175	92.175	91.942	91.942	91.709	91.709
114.245	22.046	4	12.695	92.842	95.938	92.604	94.638	92.366	93.045	92.128	92.128	91.889	91.889	91.65	91.65
113.298	25.553	4.5	12.322	92.811	95.828	92.567	94.493	92.323	92.859	92.078	92.078	91.834	91.834	91.589	91.589
112.323	29.279	5	11.949	92.778	95.71	92.527	94.34	92.277	92.66	92.026	92.026	91.774	91.774	91.523	91.523
111.319	33.246	5.5	11.575	92.743	95.585	92.485	94.176	92.228	92.449	91.97	91.97	91.711	91.711	91.453	91.453
110.282	37.477	6	11.202	92.706	95.452	92.441	94.002	92.175	92.224	91.91	91.91	91.644	91.644	91.378	91.378
109.212	42.001	6.5	10.828	92.666	95.309	92.393	93.815	92.119	92.119	91.846	91.846	91.572	91.572	91.298	91.298
108.106	46.847	7	10.455	92.623	95.156	92.341	93.615	92.06	92.06	91.777	91.777	91.495	91.495	91.212	91.212
106.961	52.052	7.5	10.082	92.577	94.992	92.286	93.4	91.995	91.995	91.704	91.704	91.412	91.412	91.12	91.12
105.775	57.658	8	9.708	92.527	94.815	92.227	93.169	91.926	91.926	91.625	91.625	91.323	91.323	91.021	91.021
104.546	63.712	8.5	9.335	92.474	94.625	92.163	92.919	91.851	91.851	91.539	91.539	91.227	91.227	90.914	90.914
103.268	70.270	9	8.962	92.416	94.418	92.093	92.649	91.77	91.77	91.447	91.447	91.123	91.123	90.798	90.798
101.939	77.399	9.5	8.588	92.353	94.193	92.018	92.355	91.682	91.682	91.346	91.346	91.009	91.009	90.673	90.673
100.555	85.176	10	8.215	92.285	93.948	91.935	92.034	91.586	91.586	91.236	91.236	90.886	90.886	90.535	90.535
99.110	93.694	10.5	7.841	92.209	93.679	91.845	91.845	91.481	91.481	91.116	91.116	90.75	90.75	90.385	90.385
97.600	103.063	11	7.468	92.127	93.384	91.746	91.746	91.365	91.365	90.983	90.983	90.601	90.601	90.219	90.219
96.017	113.419	11.5	7.095	92.035	93.057	91.636	91.636	91.237	91.237	90.837	90.837	90.437	90.437	90.036	90.036
94.354	124.925	12	6.721	91.934	92.695	91.514	91.514	91.095	91.095	90.674	90.674	90.254	90.254	89.833	89.833
92.604	137.785	12.5	6.348	91.82	92.289	91.378	91.378	90.936	90.936	90.493	90.493	90.049	90.049	89.606	89.606
90.755	152.252	13	5.974	91.693	91.833	91.225	91.225	90.757	90.757	90.288	90.288	89.819	89.819	89.35	89.35
88.797	168.649	13.5	5.601	91.548	91.548	91.051	91.051	90.554	90.554	90.057	90.057	89.559	89.559	89.06	89.06
86.714	187.387	14	5.228	91.382	91.382	90.853	90.853	90.322	90.322	89.792	89.792	89.261	89.261	88.729	88.729
84.491	209.009	14.5	4.854	91.192	91.192	90.624	90.624	90.055	90.055	89.486	89.486	88.917	88.917	88.347	88.347
82.104	234.234	15	4.481	90.969	90.969	90.356	90.356	89.743	89.743	89.13	89.13	88.516	88.516	87.902	87.902



**Table A4.15b. #2 Fuel Oil; [HHV = 135,500 Btu/gal]; [T<sub>(ambient)</sub> = 40°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis:** Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%  
**P<sub>(ambient)</sub> = 14.696 psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
120.963	0	0	0	91.539	91.037	90.532	90.026	89.518	89.008	87.982	86.948	85.906	84.855	83.796	81.654
120.196	2.285	0.5	15.309	91.489	90.976	90.461	89.945	89.427	88.906	87.86	86.805	85.742	84.671	83.591	81.406
119.41	4.685	1	14.936	91.436	90.912	90.387	89.86	89.331	88.8	87.732	86.655	85.571	84.477	83.376	81.146
118.604	7.207	1.5	14.562	91.38	90.845	90.309	89.771	89.23	88.688	87.597	86.498	85.39	84.274	83.149	80.873
117.778	9.862	2	14.189	91.321	90.775	90.227	89.677	89.124	88.57	87.455	86.332	85.2	84.06	82.911	80.585
116.93	12.661	2.5	13.816	91.259	90.701	90.14	89.577	89.013	88.446	87.306	86.158	85	83.834	82.659	80.282
116.059	15.616	3	13.442	91.194	90.622	90.049	89.473	88.895	88.315	87.148	85.973	84.789	83.596	82.394	79.962
115.165	18.739	3.5	13.069	91.125	90.539	89.952	89.362	88.77	88.176	86.982	85.778	84.566	83.344	82.113	79.623
114.245	22.046	4	12.695	91.052	90.452	89.849	89.245	88.638	88.03	86.805	85.572	84.33	83.078	81.816	79.265
113.298	25.553	4.5	12.322	90.975	90.359	89.741	89.121	88.498	87.874	86.618	85.353	84.079	82.795	81.501	78.885
112.323	29.279	5	11.949	90.892	90.26	89.625	88.989	88.35	87.708	86.419	85.121	83.812	82.494	81.167	78.481
111.319	33.246	5.5	11.575	90.805	90.154	89.502	88.848	88.191	87.532	86.208	84.873	83.529	82.175	80.81	78.051
110.282	37.477	6	11.202	90.711	90.042	89.371	88.698	88.022	87.345	85.982	84.609	83.226	81.833	80.43	77.593
109.212	42.001	6.5	10.828	90.611	89.922	89.231	88.538	87.842	87.144	85.74	84.327	82.903	81.469	80.024	77.102
108.106	46.847	7	10.455	90.504	89.794	89.081	88.366	87.649	86.929	85.482	84.024	82.557	81.078	79.589	76.577
106.961	52.052	7.5	10.082	90.389	89.655	88.92	88.182	87.441	86.698	85.204	83.7	82.185	80.658	79.121	76.013
105.775	57.658	8	9.708	90.265	89.507	88.746	87.983	87.217	86.449	84.905	83.35	81.784	80.206	78.618	75.406
104.546	63.712	8.5	9.335	90.131	89.346	88.558	87.768	86.976	86.18	84.582	82.972	81.351	79.718	78.074	74.749
103.268	70.27	9	8.962	89.986	89.172	88.355	87.536	86.714	85.889	84.232	82.563	80.882	79.19	77.485	74.039
101.939	77.399	9.5	8.588	89.829	88.983	88.134	87.283	86.43	85.573	83.851	82.118	80.373	78.615	76.844	73.266
100.555	85.176	10	8.215	89.657	88.777	87.893	87.008	86.119	85.228	83.436	81.633	79.817	77.988	76.146	72.423
99.11	93.694	10.5	7.841	89.469	88.551	87.63	86.706	85.779	84.85	82.982	81.101	79.208	77.301	75.381	71.5
97.6	103.063	11	7.468	89.262	88.302	87.339	86.374	85.406	84.434	82.482	80.517	78.538	76.546	74.539	70.485
96.017	113.419	11.5	7.095	89.033	88.027	87.018	86.007	84.992	83.975	81.929	79.87	77.798	75.711	73.609	69.363
94.354	124.925	12	6.721	88.779	87.722	86.662	85.599	84.533	83.464	81.315	79.152	76.975	74.783	72.576	68.116
92.604	137.785	12.5	6.348	88.495	87.381	86.264	85.143	84.02	82.893	80.629	78.35	76.056	73.746	71.421	66.722
90.755	152.252	13	5.974	88.175	86.997	85.815	84.631	83.443	82.251	79.857	77.447	75.022	72.58	70.121	65.154
88.797	168.649	13.5	5.601	87.813	86.562	85.307	84.05	82.789	81.524	78.982	76.424	73.849	71.258	68.649	63.377
86.714	187.387	14	5.228	87.398	86.064	84.727	83.386	82.041	80.692	77.982	75.255	72.51	69.747	66.966	61.347
84.491	209.009	14.5	4.854	86.921	85.491	84.057	82.62	81.178	79.732	76.828	73.906	70.964	68.004	65.024	59.003
82.104	234.234	15	4.481	86.363	84.821	83.276	81.726	80.172	78.613	75.482	72.331	69.161	65.97	62.758	56.27

**Table A4.16a. #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [ $T_{\text{ambient}} = 20^{\circ}\text{F}$ ]; [ $70^{\circ}\text{F} \leq \Delta T \leq 120^{\circ}\text{F}$ ].**

**Ultimate Analysis: Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%**

**$P_{\text{ambient}} = 14.696$  psia**

Flue Gas Dew Pt ( $^{\circ}\text{F}$ )	% Excess Air	% $\text{O}_2$ (dry)	% $\text{CO}_2$ (dry)	$\Delta T = 70^{\circ}\text{F}$		$\Delta T = 80^{\circ}\text{F}$		$\Delta T = 90^{\circ}\text{F}$		$\Delta T = 100^{\circ}\text{F}$		$\Delta T = 110^{\circ}\text{F}$		$\Delta T = 120^{\circ}\text{F}$	
				$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing
120.963	0	0	0	92.908	96.399	92.715	95.345	92.522	94.056	92.328	92.479	92.135	92.135	91.941	91.941
120.196	2.285	0.5	15.309	92.88	96.321	92.684	95.246	92.486	93.93	92.289	92.32	92.092	92.092	91.894	91.894
119.410	4.685	1	14.936	92.852	96.24	92.651	95.141	92.449	93.798	92.248	92.248	92.046	92.046	91.844	91.844
118.604	7.207	1.5	14.562	92.821	96.154	92.616	95.032	92.411	93.659	92.205	92.205	91.999	91.999	91.792	91.792
117.778	9.862	2	14.189	92.79	96.064	92.58	94.916	92.37	93.513	92.159	92.159	91.949	91.949	91.738	91.738
116.930	12.661	2.5	13.816	92.756	95.968	92.541	94.795	92.326	93.358	92.111	92.111	91.896	91.896	91.68	91.68
116.059	15.616	3	13.442	92.721	95.868	92.501	94.666	92.281	93.195	92.061	92.061	91.84	91.84	91.619	91.619
115.165	18.739	3.5	13.069	92.683	95.762	92.458	94.531	92.233	93.023	92.007	92.007	91.781	91.781	91.555	91.555
114.245	22.046	4	12.695	92.643	95.649	92.413	94.387	92.182	92.841	91.95	91.95	91.719	91.719	91.487	91.487
113.298	25.553	4.5	12.322	92.601	95.53	92.365	94.235	92.128	92.648	91.89	91.89	91.653	91.653	91.415	91.415
112.323	29.279	5	11.949	92.557	95.403	92.314	94.073	92.07	92.442	91.826	91.826	91.583	91.583	91.338	91.338
111.319	33.246	5.5	11.575	92.509	95.268	92.259	93.9	92.009	92.224	91.758	91.758	91.508	91.508	91.257	91.257
110.282	37.477	6	11.202	92.458	95.124	92.201	93.716	91.944	91.99	91.686	91.686	91.428	91.428	91.17	91.17
109.212	42.001	6.5	10.828	92.404	94.97	92.139	93.52	91.874	91.874	91.608	91.608	91.343	91.343	91.077	91.077
108.106	46.847	7	10.455	92.346	94.805	92.073	93.309	91.799	91.799	91.525	91.525	91.251	91.251	90.977	90.977
106.961	52.052	7.5	10.082	92.284	94.628	92.001	93.083	91.719	91.719	91.436	91.436	91.153	91.153	90.87	90.87
105.775	57.658	8	9.708	92.216	94.437	91.925	92.839	91.632	91.632	91.34	91.34	91.047	91.047	90.754	90.754
104.546	63.712	8.5	9.335	92.144	94.231	91.842	92.576	91.539	91.539	91.236	91.236	90.933	90.933	90.63	90.63
103.268	70.270	9	8.962	92.065	94.008	91.752	92.291	91.438	91.438	91.124	91.124	90.81	90.81	90.495	90.495
101.939	77.399	9.5	8.588	91.98	93.765	91.654	91.981	91.328	91.328	91.002	91.002	90.675	90.675	90.348	90.348
100.555	85.176	10	8.215	91.886	93.501	91.547	91.643	91.208	91.208	90.868	90.868	90.529	90.529	90.188	90.188
99.110	93.694	10.5	7.841	91.784	93.211	91.431	91.431	91.077	91.077	90.722	90.722	90.368	90.368	90.013	90.013
97.600	103.063	11	7.468	91.672	92.892	91.302	91.302	90.932	90.932	90.562	90.562	90.191	90.191	89.82	89.82
96.017	113.419	11.5	7.095	91.548	92.54	91.16	91.16	90.772	90.772	90.384	90.384	89.996	89.996	89.607	89.607
94.354	124.925	12	6.721	91.41	92.148	91.002	91.002	90.595	90.595	90.187	90.187	89.779	89.779	89.37	89.37
92.604	137.785	12.5	6.348	91.255	91.711	90.826	90.826	90.397	90.397	89.967	89.967	89.537	89.537	89.106	89.106
90.755	152.252	13	5.974	91.082	91.218	90.628	90.628	90.174	90.174	89.719	89.719	89.264	89.264	88.808	88.808
88.797	168.649	13.5	5.601	90.885	90.885	90.403	90.403	89.921	89.921	89.438	89.438	88.955	88.955	88.471	88.471
86.714	187.387	14	5.228	90.661	90.661	90.146	90.146	89.632	89.632	89.117	89.117	88.601	88.601	88.085	88.085
84.491	209.009	14.5	4.854	90.401	90.401	89.85	89.85	89.298	89.298	88.746	88.746	88.193	88.193	87.64	87.64
82.104	234.234	15	4.481	90.099	90.099	89.504	89.504	88.909	88.909	88.314	88.314	87.718	87.718	87.121	87.121

**Table A4.16b. #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [T<sub>(ambient)</sub> = 20°F]; [125°F ≤ ΔT ≤ 600°F].**

**Ultimate Analysis: Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%**  
**P<sub>(ambient)</sub> = 14.696 psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	ΔT = 125°F	ΔT = 150°F	ΔT = 175°F	ΔT = 200°F	ΔT = 225°F	ΔT = 250°F	ΔT = 300°F	ΔT = 350°F	ΔT = 400°F	ΔT = 450°F	ΔT = 500°F	ΔT = 600°F
				η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.	η (%) Non-Cond.
120.963	0	0	0	91.844	91.357	90.869	90.379	89.887	89.394	88.401	87.4	86.392	85.376	84.351	82.278
120.196	2.285	0.5	15.309	91.795	91.298	90.8	90.301	89.799	89.295	88.283	87.262	86.234	85.197	84.152	82.038
119.41	4.685	1	14.936	91.743	91.237	90.728	90.218	89.706	89.192	88.159	87.117	86.067	85.01	83.943	81.786
118.604	7.207	1.5	14.562	91.689	91.172	90.653	90.131	89.609	89.084	88.028	86.964	85.893	84.812	83.724	81.521
117.778	9.862	2	14.189	91.632	91.103	90.573	90.04	89.506	88.969	87.891	86.804	85.709	84.605	83.493	81.243
116.93	12.661	2.5	13.816	91.572	91.031	90.489	89.944	89.398	88.849	87.746	86.635	85.515	84.386	83.249	80.949
116.059	15.616	3	13.442	91.509	90.955	90.4	89.843	89.283	88.722	87.593	86.456	85.31	84.155	82.992	80.639
115.165	18.739	3.5	13.069	91.442	90.875	90.306	89.735	89.162	88.588	87.432	86.267	85.094	83.911	82.72	80.311
114.245	22.046	4	12.695	91.371	90.79	90.207	89.622	89.035	88.445	87.261	86.067	84.865	83.653	82.432	79.963
113.298	25.553	4.5	12.322	91.296	90.7	90.101	89.501	88.899	88.294	87.079	85.855	84.622	83.379	82.127	79.595
112.323	29.279	5	11.949	91.216	90.604	89.989	89.373	88.755	88.134	86.886	85.63	84.363	83.088	81.803	79.204
111.319	33.246	5.5	11.575	91.131	90.502	89.87	89.237	88.601	87.963	86.681	85.39	84.089	82.778	81.458	78.787
110.282	37.477	6	11.202	91.04	90.393	89.743	89.091	88.437	87.781	86.462	85.134	83.796	82.447	81.089	78.343
109.212	42.001	6.5	10.828	90.943	90.276	89.607	88.936	88.262	87.587	86.228	84.86	83.482	82.094	80.696	77.868
108.106	46.847	7	10.455	90.839	90.152	89.462	88.769	88.075	87.378	85.978	84.567	83.146	81.715	80.274	77.359
106.961	52.052	7.5	10.082	90.728	90.018	89.305	88.591	87.874	87.154	85.708	84.252	82.786	81.309	79.821	76.813
105.775	57.658	8	9.708	90.608	89.873	89.137	88.398	87.657	86.913	85.418	83.913	82.397	80.871	79.333	76.224
104.546	63.712	8.5	9.335	90.478	89.718	88.955	88.19	87.423	86.653	85.105	83.547	81.978	80.398	78.806	75.589
103.268	70.27	9	8.962	90.337	89.549	88.758	87.965	87.169	86.37	84.766	83.15	81.524	79.885	78.235	74.9
101.939	77.399	9.5	8.588	90.185	89.365	88.544	87.72	86.893	86.064	84.397	82.719	81.03	79.328	77.615	74.151
100.555	85.176	10	8.215	90.018	89.165	88.31	87.452	86.592	85.729	83.995	82.249	80.491	78.721	76.938	73.335
99.11	93.694	10.5	7.841	89.835	88.946	88.054	87.16	86.263	85.363	83.554	81.734	79.901	78.055	76.197	72.441
97.6	103.063	11	7.468	89.635	88.705	87.773	86.838	85.9	84.96	83.07	81.167	79.252	77.323	75.381	71.457
96.017	113.419	11.5	7.095	89.413	88.438	87.462	86.482	85.499	84.514	82.534	80.541	78.534	76.514	74.48	70.37
94.354	124.925	12	6.721	89.166	88.142	87.116	86.087	85.054	84.019	81.939	79.845	77.737	75.615	73.479	69.161
92.604	137.785	12.5	6.348	88.89	87.811	86.729	85.645	84.557	83.466	81.273	79.067	76.846	74.611	72.36	67.811
90.755	152.252	13	5.974	88.58	87.439	86.295	85.148	83.997	82.843	80.525	78.192	75.844	73.48	71.1	66.292
88.797	168.649	13.5	5.601	88.229	87.017	85.802	84.584	83.363	82.138	79.677	77.2	74.708	72.199	69.673	64.571
86.714	187.387	14	5.228	87.827	86.535	85.239	83.94	82.638	81.332	78.708	76.067	73.41	70.735	68.043	62.603
84.491	209.009	14.5	4.854	87.364	85.978	84.59	83.197	81.801	80.401	77.589	74.759	71.912	69.046	66.161	60.333
82.104	234.234	15	4.481	86.823	85.329	83.832	82.331	80.825	79.316	76.284	73.234	70.164	67.075	63.965	57.684

**Table A4.17a. #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [ $T_{\text{ambient}} = 30^{\circ}\text{F}$ ]; [ $60^{\circ}\text{F} \leq \Delta T \leq 110^{\circ}\text{F}$ ].**

**Ultimate Analysis:** Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%

$P_{\text{ambient}} = 14.696$  psia

Flue Gas Dew Pt ( $^{\circ}\text{F}$ )	% Excess Air	% $\text{O}_2$ (dry)	% $\text{CO}_2$ (dry)	$\Delta T = 60^{\circ}\text{F}$		$\Delta T = 70^{\circ}\text{F}$		$\Delta T = 80^{\circ}\text{F}$		$\Delta T = 90^{\circ}\text{F}$		$\Delta T = 100^{\circ}\text{F}$		$\Delta T = 110^{\circ}\text{F}$	
				$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing
120.963	0	0	0	93.074	96.566	92.881	95.511	92.688	94.223	92.495	92.645	92.301	92.301	92.107	92.107
120.196	2.285	0.5	15.309	93.051	96.492	92.854	95.416	92.657	94.101	92.459	92.49	92.262	92.262	92.064	92.064
119.410	4.685	1	14.936	93.026	96.414	92.825	95.316	92.624	93.972	92.422	92.422	92.221	92.221	92.019	92.019
118.604	7.207	1.5	14.562	93	96.333	92.795	95.211	92.589	93.838	92.384	92.384	92.177	92.177	91.971	91.971
117.778	9.862	2	14.189	92.973	96.247	92.763	95.1	92.553	93.696	92.343	92.343	92.132	92.132	91.921	91.921
116.930	12.661	2.5	13.816	92.944	96.156	92.729	94.983	92.515	93.546	92.299	92.299	92.084	92.084	91.868	91.868
116.059	15.616	3	13.442	92.914	96.061	92.694	94.86	92.474	93.389	92.254	92.254	92.033	92.033	91.813	91.813
115.165	18.739	3.5	13.069	92.882	95.96	92.657	94.729	92.431	93.222	92.206	92.206	91.98	91.98	91.754	91.754
114.245	22.046	4	12.695	92.848	95.853	92.617	94.591	92.386	93.045	92.155	92.155	91.923	91.923	91.691	91.691
113.298	25.553	4.5	12.322	92.812	95.74	92.575	94.445	92.338	92.858	92.101	92.101	91.863	91.863	91.625	91.625
112.323	29.279	5	11.949	92.773	95.619	92.53	94.289	92.287	92.659	92.043	92.043	91.799	91.799	91.555	91.555
111.319	33.246	5.5	11.575	92.732	95.491	92.483	94.124	92.232	92.447	91.982	91.982	91.731	91.731	91.48	91.48
110.282	37.477	6	11.202	92.689	95.354	92.432	93.947	92.174	92.221	91.917	91.917	91.659	91.659	91.4	91.4
109.212	42.001	6.5	10.828	92.642	95.208	92.378	93.758	92.112	92.112	91.847	91.847	91.581	91.581	91.315	91.315
108.106	46.847	7	10.455	92.593	95.052	92.319	93.556	92.046	92.046	91.772	91.772	91.498	91.498	91.223	91.223
106.961	52.052	7.5	10.082	92.539	94.884	92.257	93.338	91.974	91.974	91.692	91.692	91.409	91.409	91.125	91.125
105.775	57.658	8	9.708	92.482	94.702	92.19	93.104	91.898	91.898	91.605	91.605	91.313	91.313	91.02	91.02
104.546	63.712	8.5	9.335	92.419	94.507	92.117	92.852	91.815	91.815	91.512	91.512	91.209	91.209	90.905	90.905
103.268	70.270	9	8.962	92.352	94.295	92.038	92.578	91.725	91.725	91.411	91.411	91.096	91.096	90.782	90.782
101.939	77.399	9.5	8.588	92.279	94.064	91.953	92.28	91.627	91.627	91.301	91.301	90.974	90.974	90.647	90.647
100.555	85.176	10	8.215	92.199	93.813	91.86	91.956	91.52	91.52	91.181	91.181	90.841	90.841	90.501	90.501
99.110	93.694	10.5	7.841	92.111	93.538	91.757	91.757	91.404	91.404	91.049	91.049	90.695	90.695	90.34	90.34
97.600	103.063	11	7.468	92.015	93.235	91.645	91.645	91.275	91.275	90.905	90.905	90.534	90.534	90.163	90.163
96.017	113.419	11.5	7.095	91.908	92.9	91.521	91.521	91.133	91.133	90.745	90.745	90.357	90.357	89.968	89.968
94.354	124.925	12	6.721	91.79	92.529	91.383	91.383	90.975	90.975	90.568	90.568	90.159	90.159	89.751	89.751
92.604	137.785	12.5	6.348	91.658	92.113	91.229	91.229	90.799	90.799	90.369	90.369	89.939	89.939	89.508	89.508
90.755	152.252	13	5.974	91.509	91.645	91.055	91.055	90.601	90.601	90.146	90.146	89.691	89.691	89.235	89.235
88.797	168.649	13.5	5.601	91.341	91.341	90.858	90.858	90.376	90.376	89.893	89.893	89.41	89.41	88.926	88.926
86.714	187.387	14	5.228	91.148	91.148	90.634	90.634	90.119	90.119	89.604	89.604	89.089	89.089	88.573	88.573
84.491	209.009	14.5	4.854	90.926	90.926	90.374	90.374	89.823	89.823	89.27	89.27	88.718	88.718	88.165	88.165
82.104	234.234	15	4.481	90.666	90.666	90.072	90.072	89.477	89.477	88.881	88.881	88.285	88.285	87.689	87.689

**Table A4.17b. #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [ $T_{(ambient)} = 30^{\circ}\text{F}$ ]; [ $125^{\circ}\text{F} \leq \Delta T \leq 600^{\circ}\text{F}$ ].****Ultimate Analysis: Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%** **$P_{(ambient)} = 14.696$  psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	$\Delta T = 125^{\circ}\text{F}$	$\Delta T = 150^{\circ}\text{F}$	$\Delta T = 175^{\circ}\text{F}$	$\Delta T = 200^{\circ}\text{F}$	$\Delta T = 225^{\circ}\text{F}$	$\Delta T = 250^{\circ}\text{F}$	$\Delta T = 300^{\circ}\text{F}$	$\Delta T = 350^{\circ}\text{F}$	$\Delta T = 400^{\circ}\text{F}$	$\Delta T = 450^{\circ}\text{F}$	$\Delta T = 500^{\circ}\text{F}$	$\Delta T = 600^{\circ}\text{F}$
				$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.
120.963	0	0	0	91.816	91.329	90.84	90.349	89.857	89.362	88.368	87.366	86.356	85.338	84.312	82.235
120.196	2.285	0.5	15.309	91.767	91.27	90.771	90.27	89.768	89.264	88.25	87.227	86.197	85.159	84.113	81.995
119.41	4.685	1	14.936	91.715	91.208	90.699	90.188	89.675	89.161	88.125	87.082	86.031	84.971	83.904	81.743
118.604	7.207	1.5	14.562	91.661	91.143	90.623	90.101	89.578	89.052	87.995	86.93	85.856	84.774	83.684	81.478
117.778	9.862	2	14.189	91.604	91.075	90.543	90.01	89.475	88.938	87.857	86.769	85.672	84.567	83.453	81.199
116.93	12.661	2.5	13.816	91.544	91.003	90.459	89.914	89.366	88.817	87.712	86.599	85.478	84.348	83.209	80.905
116.059	15.616	3	13.442	91.481	90.927	90.37	89.812	89.252	88.69	87.56	86.421	85.273	84.117	82.951	80.594
115.165	18.739	3.5	13.069	91.414	90.846	90.276	89.705	89.131	88.556	87.398	86.232	85.056	83.872	82.679	80.266
114.245	22.046	4	12.695	91.343	90.761	90.177	89.591	89.003	88.413	87.227	86.031	84.827	83.614	82.391	79.919
113.298	25.553	4.5	12.322	91.268	90.671	90.072	89.471	88.867	88.262	87.045	85.819	84.584	83.34	82.086	79.55
112.323	29.279	5	11.949	91.188	90.575	89.96	89.343	88.723	88.102	86.852	85.594	84.326	83.048	81.761	79.158
111.319	33.246	5.5	11.575	91.103	90.473	89.84	89.206	88.57	87.931	86.647	85.354	84.051	82.738	81.416	78.742
110.282	37.477	6	11.202	91.012	90.364	89.713	89.061	88.406	87.749	86.428	85.097	83.757	82.407	81.047	78.297
109.212	42.001	6.5	10.828	90.915	90.247	89.577	88.905	88.231	87.554	86.194	84.824	83.444	82.054	80.653	77.821
108.106	46.847	7	10.455	90.811	90.122	89.432	88.739	88.043	87.346	85.943	84.53	83.108	81.675	80.231	77.312
106.961	52.052	7.5	10.082	90.7	89.988	89.275	88.56	87.842	87.121	85.673	84.215	82.747	81.268	79.778	76.765
105.775	57.658	8	9.708	90.579	89.844	89.107	88.367	87.625	86.88	85.383	83.876	82.358	80.829	79.289	76.176
104.546	63.712	8.5	9.335	90.45	89.688	88.925	88.159	87.39	86.62	85.07	83.51	81.938	80.356	78.762	75.54
103.268	70.27	9	8.962	90.309	89.519	88.728	87.933	87.137	86.337	84.73	83.113	81.484	79.843	78.191	74.851
101.939	77.399	9.5	8.588	90.156	89.336	88.513	87.688	86.861	86.03	84.361	82.681	80.989	79.286	77.57	74.101
100.555	85.176	10	8.215	89.989	89.136	88.28	87.421	86.56	85.696	83.959	82.211	80.45	78.678	76.892	73.284
99.11	93.694	10.5	7.841	89.807	88.916	88.024	87.128	86.23	85.329	83.518	81.695	79.86	78.012	76.15	72.389
97.6	103.063	11	7.468	89.606	88.675	87.742	86.806	85.867	84.925	83.033	81.128	79.21	77.279	75.334	71.404
96.017	113.419	11.5	7.095	89.384	88.409	87.431	86.45	85.466	84.48	82.497	80.501	78.492	76.469	74.432	70.316
94.354	124.925	12	6.721	89.137	88.112	87.085	86.054	85.021	83.984	81.901	79.805	77.694	75.569	73.43	69.107
92.604	137.785	12.5	6.348	88.861	87.781	86.698	85.612	84.523	83.431	81.236	79.027	76.803	74.564	72.31	67.755
90.755	152.252	13	5.974	88.551	87.409	86.263	85.115	83.963	82.808	80.487	78.151	75.8	73.433	71.05	66.235
88.797	168.649	13.5	5.601	88.2	86.987	85.771	84.551	83.328	82.102	79.638	77.159	74.663	72.151	69.621	64.512
86.714	187.387	14	5.228	87.798	86.504	85.207	83.907	82.603	81.295	78.668	76.024	73.364	70.685	67.989	62.543
84.491	209.009	14.5	4.854	87.334	85.948	84.558	83.164	81.766	80.365	77.549	74.716	71.865	68.995	66.106	60.27
82.104	234.234	15	4.481	86.794	85.298	83.799	82.297	80.79	79.279	76.243	73.189	70.116	67.022	63.909	57.619

**Table A4.18a. #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [ $T_{\text{ambient}} = 40^{\circ}\text{F}$ ]; [ $50^{\circ}\text{F} \leq \Delta T \leq 100^{\circ}\text{F}$ ].**

**Ultimate Analysis:** Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%

$P_{\text{ambient}} = 14.696$  psia

Flue Gas Dew Pt ( $^{\circ}\text{F}$ )	% Excess Air	% $\text{O}_2$ (dry)	% $\text{CO}_2$ (dry)	$\Delta T = 50^{\circ}\text{F}$		$\Delta T = 60^{\circ}\text{F}$		$\Delta T = 70^{\circ}\text{F}$		$\Delta T = 80^{\circ}\text{F}$		$\Delta T = 90^{\circ}\text{F}$		$\Delta T = 100^{\circ}\text{F}$	
				$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing	$\eta$ (%) Non-Cond.	$\eta$ (%) Condensing
120.963	0	0	0	93.241	96.732	93.048	95.678	92.855	94.389	92.661	92.812	92.468	92.274	92.274	92.274
120.196	2.285	0.5	15.309	93.221	96.662	93.024	95.587	92.827	94.271	92.63	92.661	92.432	92.432	92.234	92.234
119.410	4.685	1	14.936	93.201	96.589	93	95.49	92.799	94.147	92.597	92.597	92.395	92.395	92.193	92.193
118.604	7.207	1.5	14.562	93.179	96.512	92.974	95.389	92.768	94.017	92.562	92.562	92.356	92.356	92.15	92.15
117.778	9.862	2	14.189	93.156	96.43	92.946	95.283	92.736	93.879	92.526	92.526	92.315	92.315	92.105	92.105
116.930	12.661	2.5	13.816	93.132	96.345	92.918	95.171	92.703	93.735	92.488	92.488	92.272	92.272	92.057	92.057
116.059	15.616	3	13.442	93.107	96.254	92.887	95.053	92.667	93.582	92.447	92.447	92.227	92.227	92.006	92.006
115.165	18.739	3.5	13.069	93.08	96.159	92.855	94.928	92.63	93.421	92.404	92.404	92.178	92.178	91.952	91.952
114.245	22.046	4	12.695	93.052	96.058	92.821	94.795	92.59	93.25	92.359	92.359	92.127	92.127	91.896	91.896
113.298	25.553	4.5	12.322	93.022	95.95	92.785	94.655	92.548	93.068	92.311	92.311	92.073	92.073	91.835	91.835
112.323	29.279	5	11.949	92.99	95.836	92.747	94.506	92.503	92.876	92.26	92.26	92.016	92.016	91.772	91.772
111.319	33.246	5.5	11.575	92.956	95.715	92.706	94.347	92.456	92.671	92.205	92.205	91.955	91.955	91.704	91.704
110.282	37.477	6	11.202	92.92	95.585	92.663	94.178	92.405	92.452	92.147	92.147	91.889	91.889	91.631	91.631
109.212	42.001	6.5	10.828	92.881	95.447	92.616	93.997	92.351	92.351	92.085	92.085	91.82	91.82	91.553	91.553
108.106	46.847	7	10.455	92.839	95.299	92.566	93.803	92.293	92.293	92.019	92.019	91.745	91.745	91.47	91.47
106.961	52.052	7.5	10.082	92.795	95.139	92.513	93.594	92.23	92.23	91.947	91.947	91.664	91.664	91.381	91.381
105.775	57.658	8	9.708	92.747	94.968	92.455	93.37	92.163	92.163	91.871	91.871	91.578	91.578	91.285	91.285
104.546	63.712	8.5	9.335	92.695	94.782	92.393	93.127	92.09	92.09	91.788	91.788	91.484	91.484	91.181	91.181
103.268	70.270	9	8.962	92.639	94.582	92.325	92.865	92.012	92.012	91.698	91.698	91.383	91.383	91.069	91.069
101.939	77.399	9.5	8.588	92.578	94.364	92.252	92.579	91.926	91.926	91.6	91.6	91.273	91.273	90.946	90.946
100.555	85.176	10	8.215	92.511	94.126	92.172	92.268	91.833	91.833	91.493	91.493	91.153	91.153	90.813	90.813
99.110	93.694	10.5	7.841	92.438	93.865	92.085	92.085	91.731	91.731	91.376	91.376	91.022	91.022	90.667	90.667
97.600	103.063	11	7.468	92.358	93.578	91.988	91.988	91.618	91.618	91.248	91.248	90.877	90.877	90.506	90.506
96.017	113.419	11.5	7.095	92.269	93.261	91.882	91.882	91.494	91.494	91.106	91.106	90.717	90.717	90.329	90.329
94.354	124.925	12	6.721	92.171	92.909	91.763	91.763	91.356	91.356	90.948	90.948	90.54	90.54	90.131	90.131
92.604	137.785	12.5	6.348	92.06	92.516	91.631	91.631	91.202	91.202	90.772	90.772	90.342	90.342	89.911	89.911
90.755	152.252	13	5.974	91.936	92.073	91.482	91.482	91.028	91.028	90.573	90.573	90.118	90.118	89.663	89.663
88.797	168.649	13.5	5.601	91.796	91.796	91.314	91.314	90.831	90.831	90.349	90.349	89.865	89.865	89.382	89.382
86.714	187.387	14	5.228	91.635	91.635	91.121	91.121	90.607	90.607	90.092	90.092	89.576	89.576	89.06	89.06
84.491	209.009	14.5	4.854	91.45	91.45	90.899	90.899	90.347	90.347	89.795	89.795	89.242	89.242	88.689	88.689
82.104	234.234	15	4.481	91.234	91.234	90.64	90.64	90.045	90.045	89.449	89.449	88.853	88.853	88.257	88.257

**Table A4.18b. #2 Fuel Oil; [HHV = 139,600 Btu/gal]; [ $T_{(ambient)} = 40^{\circ}\text{F}$ ]; [ $125^{\circ}\text{F} \leq \Delta T \leq 600^{\circ}\text{F}$ ].****Ultimate Analysis: Carbon – 87.2%; Hydrogen – 12.54%; Oxygen – 0.04%; Sulfur – 0.22%** **$P_{(ambient)} = 14.696$  psia**

Flue Gas Dew Pt (°F)	% Excess Air	% O <sub>2</sub> (dry)	% CO <sub>2</sub> (dry)	$\Delta T = 125^{\circ}\text{F}$	$\Delta T = 150^{\circ}\text{F}$	$\Delta T = 175^{\circ}\text{F}$	$\Delta T = 200^{\circ}\text{F}$	$\Delta T = 225^{\circ}\text{F}$	$\Delta T = 250^{\circ}\text{F}$	$\Delta T = 300^{\circ}\text{F}$	$\Delta T = 350^{\circ}\text{F}$	$\Delta T = 400^{\circ}\text{F}$	$\Delta T = 450^{\circ}\text{F}$	$\Delta T = 500^{\circ}\text{F}$	$\Delta T = 600^{\circ}\text{F}$
				$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.	$\eta$ (%) Non-Cond.
120.963	0	0	0	91.788	91.3	90.81	90.319	89.826	89.331	88.335	87.331	86.319	85.3	84.272	82.193
120.196	2.285	0.5	15.309	91.739	91.241	90.742	90.24	89.737	89.232	88.216	87.193	86.161	85.121	84.073	81.952
119.41	4.685	1	14.936	91.687	91.179	90.669	90.158	89.644	89.129	88.092	87.047	85.994	84.933	83.864	81.7
118.604	7.207	1.5	14.562	91.633	91.114	90.594	90.071	89.547	89.02	87.961	86.894	85.819	84.736	83.644	81.434
117.778	9.862	2	14.189	91.576	91.046	90.514	89.98	89.444	88.906	87.824	86.734	85.635	84.528	83.412	81.155
116.93	12.661	2.5	13.816	91.516	90.974	90.43	89.883	89.335	88.785	87.679	86.564	85.441	84.309	83.168	80.861
116.059	15.616	3	13.442	91.453	90.898	90.341	89.782	89.221	88.658	87.526	86.385	85.236	84.078	82.911	80.55
115.165	18.739	3.5	13.069	91.386	90.817	90.247	89.674	89.1	88.523	87.364	86.196	85.019	83.833	82.638	80.221
114.245	22.046	4	12.695	91.315	90.732	90.147	89.561	88.972	88.381	87.193	85.996	84.79	83.574	82.35	79.874
113.298	25.553	4.5	12.322	91.24	90.642	90.042	89.44	88.836	88.23	87.011	85.783	84.546	83.3	82.044	79.505
112.323	29.279	5	11.949	91.16	90.546	89.93	89.312	88.692	88.069	86.818	85.558	84.288	83.008	81.719	79.113
111.319	33.246	5.5	11.575	91.075	90.444	89.81	89.175	88.538	87.898	86.613	85.317	84.012	82.698	81.374	78.695
110.282	37.477	6	11.202	90.984	90.335	89.683	89.03	88.374	87.716	86.393	85.061	83.719	82.367	81.005	78.25
109.212	42.001	6.5	10.828	90.887	90.218	89.547	88.874	88.199	87.521	86.159	84.787	83.405	82.013	80.61	77.775
108.106	46.847	7	10.455	90.783	90.093	89.402	88.708	88.011	87.313	85.908	84.494	83.069	81.634	80.188	77.265
106.961	52.052	7.5	10.082	90.671	89.959	89.245	88.528	87.81	87.088	85.638	84.178	82.708	81.226	79.734	76.717
105.775	57.658	8	9.708	90.551	89.815	89.076	88.336	87.593	86.847	85.348	83.839	82.319	80.788	79.245	76.128
104.546	63.712	8.5	9.335	90.421	89.659	88.894	88.127	87.358	86.586	85.034	83.472	81.899	80.314	78.718	75.491
103.268	70.27	9	8.962	90.28	89.49	88.697	87.902	87.104	86.304	84.695	83.075	81.443	79.801	78.146	74.801
101.939	77.399	9.5	8.588	90.128	89.306	88.483	87.657	86.828	85.997	84.325	82.643	80.949	79.243	77.524	74.051
100.555	85.176	10	8.215	89.961	89.106	88.249	87.389	86.527	85.662	83.923	82.172	80.409	78.634	76.846	73.233
99.11	93.694	10.5	7.841	89.778	88.887	87.993	87.096	86.197	85.295	83.481	81.656	79.818	77.967	76.104	72.337
97.6	103.063	11	7.468	89.577	88.645	87.711	86.774	85.834	84.891	82.996	81.089	79.168	77.234	75.287	71.351
96.017	113.419	11.5	7.095	89.355	88.379	87.4	86.418	85.433	84.445	82.46	80.461	78.449	76.424	74.384	70.262
94.354	124.925	12	6.721	89.108	88.082	87.054	86.022	84.987	83.949	81.864	79.764	77.651	75.523	73.381	69.052
92.604	137.785	12.5	6.348	88.832	87.751	86.667	85.58	84.489	83.395	81.198	78.986	76.759	74.517	72.26	67.699
90.755	152.252	13	5.974	88.522	87.378	86.232	85.082	83.929	82.772	80.448	78.109	75.755	73.385	70.999	66.177
88.797	168.649	13.5	5.601	88.17	86.956	85.739	84.518	83.294	82.066	79.599	77.116	74.617	72.102	69.569	64.453
86.714	187.387	14	5.228	87.768	86.474	85.175	83.874	82.568	81.259	78.628	75.981	73.317	70.635	67.935	62.481
84.491	209.009	14.5	4.854	87.305	85.917	84.525	83.13	81.731	80.327	77.508	74.672	71.817	68.943	66.05	60.207
82.104	234.234	15	4.481	86.764	85.267	83.767	82.262	80.754	79.241	76.202	73.144	70.066	66.969	63.851	57.554