8506

NFPA 8506
Standard on Heat Recovery Steam Generator Systems
1995 Edition

NFPA

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Standards-Making Organization

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The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

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Standard on

Heat Recovery Steam Generator Systems

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This edition of NFPA 8506, *Standard on Heat Recovery Steam Generator Systems*, was prepared by the Technical Committee on Heat Recovery Steam Generators, released by the Technical Correlating Committee on Boiler Combustion System Hazards, and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 8506 was approved as an American National Standard on August 11, 1995.

Origin and Development of NFPA 8506

With the increased use of heat recovery steam generators in industry, a technical committee was formed in 1993 to prepare a standard covering heat recovery steam generators. This document is the result of the work of this committee. This is the first edition of NFPA 8506 and is similar in organization to the other documents in 8500 series boiler combustion system hazards standards.

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NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the reduction of combustion system hazards in commercial, industrial, and utility boilers with a heat input rate of 12,500,000 Btu/hr and above. This includes all fuels or heat inputs except nuclear. Also responsible for documents on the reduction of hazards in pulverized fuel systems and stoker-fired boilers with a heat input rate of 400,000 Btu/hr and above.

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NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents covering the operation of heat recovery steam generators and the related reduction of combustion system hazards and prevention of boiler furnace explosions. This includes all fuels at any heat input rate.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 11 and Appendix D.

Foreword

Technological advances in recent years and, in particular, the pervasiveness of microprocessor-based hardware make it important that only highly qualified individuals be employed in the translation of these guidelines into operating systems. Each type of hardware has its own unique features and operational modes. It is vital that the designer of the safety system be completely familiar with the features, characteristics, and limitations of the specific hardware and also possess a thorough understanding of this standard and its intent.

It is not possible for this standard to encompass the specific hardware applications, nor should it be considered a "cookbook" for the design of a safety system.

Where applying any type of equipment to a safety system, the designer should consider carefully all of the possible failure modes and the effect that each might have on the integrity of the system and the safety of the unit and personnel. In particular, no single point failure should result in an unsafe or uncontrollable condition or a masked failure of a microprocessor-based system that could result in the operator unwittingly taking action that could lead to an unsafe condition.

This document is intended to be used for the design, installation, operation, and maintenance of heat recovery steam generators and their burner management and combustion control systems.

Chapter 1 Introduction

1-1 Scope.

1-1.1 This standard shall apply to steam generators that recover heat from a combustion turbine firing the following fuels either alone or in combination:

(a) Natural gas;

(b) No. 2 fuel oil;

(c) Kerosene;

(d) JP-4 jet fuel;

(e) Diesel fuel.

The steam generator shall be permitted to be unfired, or supplemental firing shall be permitted to be provided from natural gas or fuel oil, as defined in this standard.

1-1.2 The intent of this standard is not to dictate the methods or details of the combustion turbine manufacturer's product or control system. Specific functional considerations are identified for proper interfacing related to the safety aspects of the combined combustion turbine and the HRSG.

1-1.3 This standard does not cover simultaneous firing of more than one fuel in the supplemental firing of the steam generator. Simultaneous firing involves requirements that are not addressed by this document.

1-1.4 This standard is not retroactive. This standard shall apply to new installations and to major alterations or extensions of existing equipment for the preparation and burning of fuel contracted for six months subsequent to the date of issue of this document.

1-1.5 This standard does not specifically address the firing of fuels other than those specified in 1-1.1. This standard is intended to apply to other fuels not covered by 1-1.1 (*see 1-2.2*). Other fuels can have unique characteristics requiring special design and operation considerations for fuel handling, purging, and burning.

1-1.6 Since the standard is based on the present state of the art, its application to existing installations shall not be required. Nevertheless, operating companies are encouraged to adopt those features of the standard that are considered applicable and reasonable for existing installations.

1-1.7 This standard does not address multiple combustion turbines exhausting into a single heat recovery steam generator (HRSG). Any system applying this concept shall require special design considerations that are not addressed in this standard.

1-1.8 The standard shall be applied with consideration of the document as a whole. Chapters 1 and 2 are introductory and provide general guidelines and focus. Where any real or perceived conflict exists, the guidelines outlined in subsequent chapters shall be followed.

1-1.9 Chapters 1 through 8 address fired or unfired HRSGs directly coupled to combustion turbine exhaust without intervening dampers or a bypass stack.

1-1.10 Chapter 9 (reserved) eventually will address HRSG systems with bypass dampers and systems using supplementary sources of combustion air.

1-1.11 Chapter 10 (reserved) eventually will address fired HRSGs where the primary source of heat is from burners rather than from the heat content of the combustion turbine exhaust.

1-2 Purpose.

1-2.1 The purpose of this document shall be to contribute to operating safety and to prevent explosions, implosions, and uncontrolled fires in HRSG sections and exhaust ductwork. It shall establish minimum standards for the design, installation, operation, and maintenance of heat recovery steam generators and their fuel-burning, air supply, and combustion products removal systems. The standard shall require the coordination of operating procedures and components, control systems, interlocks, and structural design. The standard shall further require the establishment of training programs in equipment operation and maintenance, for both new and existing personnel, to ensure that minimum standards for operation and maintenance are understood and followed.

1-2.2 No standard can guarantee the elimination of HRSG explosions and implosions. Technology in this area is under constant development and is reflected in revisions to this standard. The user of this standard shall recognize the complexity of firing with regard to the type of equipment used and the characteristics of the fuel. Therefore, the designer is cautioned that the standard is not a design handbook. The standard does not eliminate the need for the engineer or for competent engineering judgment. It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of such designs. In such cases, the designer is responsible for demonstrating the validity of the approach.

1-2.3 Emphasis is placed on the importance of component coordination and on knowledge of expected operating conditions, along with adequate structure strength, proper operation and maintenance procedures, combustion and draft control equipment, safety interlocks, alarms, trips, and other related controls that are essential to proper operation.

1-2.4 The effect of gas cleanup systems located within or downstream of the HRSG shall be considered in the design and operation of the system.

Chapter 2 General

2-1 HRSG Fires and Explosions.

2-1.1 The basic cause of uncontrolled fires or explosions in an HRSG system is the ignition of an accumulated combustible mixture within the HRSG enclosure.

2-1.2 A dangerous combustible mixture within the HRSG sections and ductwork consists of the accumulation of combustibles mixed with air in proportions that result in uncontrolled combustion when an ignition source is supplied. An explosion might result from ignition of this accumulation if the quantity of combustible mixture and the proportion of air to fuel are such that an explosive force is created within the HRSG enclosure. The magnitude and intensity of the explosion depends on both the relative quantity of combustibles that has accumulated and the proportion of air that mixes with them at the moment of ignition. Explosions, including "puffs," are the result of improper procedures used by operating personnel, improper design of equipment or control systems, or equipment or control system malfunction.

2-1.3 Numerous situations can arise in connection with the operation of an HRSG that produce uncontrolled combustion conditions. These situations include:

(a) An interruption of the fuel or combustion air supply or ignition energy to the burners, sufficient to result in a momentary loss of flame, followed by the delayed reignition of an accumulation of combustibles.

(b) Fuel leakage into the enclosure and the ignition of the accumulation by a spark or other source of ignition.

(c) Repeated unsuccessful attempts to light off the combustion turbine or supplementary fired burners without appropriate purging, resulting in the accumulation of an explosive mixture.

(d) The accumulation of an explosive mixture of fuel and combustion air as a result of loss of flame or incomplete combustion at one or more burners in the presence of other burners operating normally or during light-off of additional burners.

(e) The accumulation of an explosive mixture of fuel and combustion air as a result of a complete burner flameout and the ignition of the accumulation by a spark or other ignition source, such as an attempt to light off burners without adequate purge.

2-1.4 An examination of reports of steam generator explosions suggests that the occurrence of small explosions, puffs, or near-misses are far more frequent than usually is recognized. Improved instrumentation, safety interlocks and protective devices, proper operating sequences, and a clearer understanding of the problem by designers, operators, and maintenance personnel can reduce greatly the risks and actual incidence of HRSG explosions.

2-1.5 In an HRSG with supplementary firing, upset conditions or control malfunction can lead to an air/fuel mixture that could result in a flameout followed by reignition after a combustible mixture has been reestablished. Dead pockets might exist in HRSG sections and ductwork or other parts of the unit where combustible mixtures can accumulate under upset conditions. These accumulations can ignite with explosive force in the presence of an ignition source.

2-1.6 Statistics indicate that human error is a contributing factor in the majority of explosions. It is important to consider whether the error is the result of:

(a) Unfavorable operating characteristics of the equipment or its control;

(b) Lack of functional coordination of the various components of the steam-generating system and its controls; or

(c) Lack of understanding of, or failure to follow, proper operating procedures, safeguards, and equipment operation recommendations.

2-1.7 HRSG Enclosure, Fin-Tube Fires.

NOTE: Due to misoperation, there have been occurrences of fin-metal fires in HRSGs, and there is a need to address this potential.

2-1.7.1 Consideration shall be given to detecting and alarming fin-metal fires.

2-1.7.2 A procedure shall be provided to contain (i.e., confine or seal-off) a fin-metal fire and to protect the buildings and adjacent equipment.

2-1.7.3 The initial response shall include the removal of all fuel from the combustion turbine and the HRSG.

2-2 HRSG Implosions. For HRSGs that use an induced draft fan where the potential exists for excessively low HRSG enclosure gas side pressures, the HRSG enclosure shall conform with the requirements of NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers*, Chapter 5.

2-3 Manufacture, Design, and Engineering.

2-3.1 The owner or the owner's agent shall, in cooperation with the manufacturer, ensure that the unit is not deficient in apparatus that is necessary for proper operation with respect to pressure parts, fuel-burning equipment, combustion air and fuel, and safe light-off and maintenance of stable flame.

2-3.2 All fuel systems shall include provisions to prevent foreign substances from interfering with the fuel supply to the duct burner.

2-3.3 An evaluation shall be made to determine the optimum integration of manual and automatic safety features considering the advantages and disadvantages of each trip function.

NOTE: The maximum number of automatic trip features does not necessarily provide for maximum overall safety. Some trip actions result in additional operations that increase exposure to hazards.

2-3.4 This standard shall require a minimum degree of automation. However, in the cases of more complex plants, plants with increased automation, and plants designed for remote operation, the following minimum provisions shall be required:

(a) Information on significant operating events that allow the operator to make rapid evaluation of the operating situation;

(b) Continuous and usable displays of variables in the normal control location that allow the operator to avoid unsafe operation;

(c) Additional automated control points that allow a remotely located operator to control the unit safely;

(d) In-service maintenance and checking of system functions without impairment of the reliability of the overall control system;

(e) Control areas environmentally designed to provide suitable conditions for personnel, control equipment, or both; and

(f) Visual displays and alarms that are easily identifiable and readable.

2-3.5 The duct burner piping and equipment shall be designed and constructed to prevent the formation of hazardous concentrations of combustible gases under any operating conditions.

2-4 Basic Operating Objectives.

2-4.1 Basic operating objectives shall include the requirements of this section.

2-4.1.1 Standard operating procedures shall be established that result in well-defined and controlled operations. All operating procedures shall be rigidly enforced at all times.

2-4.1.2 Interlocks shall be used to minimize improper operating sequences and to interrupt sequences when conditions are unsafe for continuation.

2-4.1.3 No interlocks shall be bypassed during start-up or operation of the unit unless the bypass is alarmed and is governed by operating procedures.

2-4.1.4 The mass flow of combustion air to the duct burner system shall be maintained at or above its purge rate and within the duct burner design operating range during all operations of the duct burner system.

2-4.2 Written operating procedures and detailed checklists for operator guidance shall be provided for achieving these basic operating objectives. All manual and automatic functions shall be included in these procedures and checklists.

Chapter 3 Definitions

3-1 Definitions. The following definitions shall apply to this standard.

Air, Combustion. The air used to fuel the combustion process. For duct burners, this generally is combustion turbine exhaust. (See "Air, Primary" and "Air, Vitiated.")

Air, Excess. Air supplied for combustion in excess of theoretical air.

NOTE: This is not "Air-Rich" as defined in this section.

Air, Furnace Purge. See "Purge, Combustion Turbine," "Purge, Duct Burner," and "Purge Rate."

Air, Primary. The air that is contained in the combustion turbine exhaust.

Air, Seal. Air supplied to any device at pressure for the specified purpose of minimizing contamination.

Air, Secondary. The air for combustion supplied to the burners by the forced draft fan.

Air, Stoichiometric. See "Air, Theoretical."

Air, Tertiary. The air supplied to certain types of burners for cooling the burner metal or to improve the combustion process.

Air, Theoretical. The chemically correct quantity of air needed for complete combustion of a given quantity of a specific fuel.

Air/Fuel Ratio. A ratio of air to fuel supplied to a combustion process.

Air-Rich. Indicates a ratio of air to fuel supplied to a combustion process that provides more than the minimum excess air needed for optimum combustion of the fuel.

Air, Vitiated. Air with an oxygen content below normal; for example, combustion turbine exhaust.

Alarm. An audible or visible signal indicating an off-standard or abnormal condition.

Approved. Acceptable to the authority having jurisdiction.

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Atomizer. A device in a burner that emits liquid fuel in a finely divided state.

Atomizer, Mechanical. A device in an oil burner that emits liquid fuel in a finely divided state without using an atomizing medium.

Atomizing Medium. A supplementary fluid, such as steam or air, that assists in breaking down liquid fuel into a finely divided state.

Augmented Air Firing. Supplementary firing with the addition of air at the duct burners to support and stabilize combustion.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Auxiliary Firing. See "Supplementary Firing."

Availability. The percent of time during a fixed period that a generating unit is capable of providing functional operating service.

Burner. A device or group of devices for the introduction of fuel and air at the velocities, turbulence, and concentration necessary to maintain ignition and combustion of the fuel.

Burner Management System. The control system dedicated to combustion safety, operator assistance in the starting and stopping of fuel-burning equipment, and prevention of misoperation and damage. The burner management system includes the following functions specified in this standard:

(a) Interlock system;
(b) Fuel trip system;
(c) Master fuel trip system;
(d) Master fuel trip relay;
(e) Flame monitoring and tripping systems;
(f) Ignition subsystem; and
(g) Duct burner subsystem.

Combustion Control System. The control system that regulates the fuel input (and air, if applicable) to maintain continuous combustion and stable flame. This control system might include drum level, desuperheater spray, or draft control, where applicable.

Combustion Turbine. A turbine in which the rotating element is actuated by the pressure of combustion gases on curved vanes.

Commercial Operation. The date that the full plant capacity is formally added to the power grid.

Commissioning. The time period of plant testing and operation between initial operation and commercial operation.

Damper, Tight Shutoff. A close-fitting damper to inhibit leakage of air or flue gas into any system component.

Directional Blocking. An interlock that, upon detection of significant error in HRSG process variables, acts to inhibit the movement of all appropriate final control elements in the direction that increases the error.

Drip Leg. A chamber of ample volume, with suitable clean-out and drain connections, over which fuel gas is passed so that liquids and solids are trapped.

Duct Burner. A burner located in a duct ahead of or within an HRSG section.

Explosive Mixture. A flammable or combustible mixture in a confined space.

Fan, Seal Air. A fan used to supply sealing air.

Fan Test Block Capability. The point on the head versus the flow characteristics curve at which the fan is selected. This is the calculated operating point associated with the maximum continuous rating of the steam generator furnace plus the head and flow margins.

Flame. The visible or other physical evidence of the chemical process of rapid conversion of fuel and air into products of combustion.

Flame Detector. A device that senses the presence or absence of flame and provides a usable signal.

Flame Detector, Self-Checking. A flame detector that automatically, and at regular intervals, tests the entire sensing and signal processing system of the flame detector. This ensures that the failure of any single component cannot result in a false indication of flame.

Flame Envelope. The confines (not necessarily visible) of an independent process that converts fuel and air into products of combustion.

Fresh Air Mode. The operation of an HRSG with atmospheric instead of combustion turbine exhaust.

Fuel Cutback. An action of the combustion control system to reduce fuel flow.

Fuel Gas. See "LP-Gas" and "Natural Gas."

Fuel, JP4. A light, volatile fuel with a boiling point between gasoline and light distillate. Its properties are defined in MIL-T-5624, *Turbine Fuel, Aviation, Grade JP4, JP5, and JP5/JP8 ST,* and are similar to ASTM D1655, *Standard Specification for Aviation Turbine Fuels* (Jet B), and ASTM D2880, *Standard Specification for Gas Turbine Fuel Oils* (OGT).

Fuel, Kerosene. A light, highly refined fuel. It is slightly more volatile than No. 2 fuel oil. Its properties are defined in ASTM D396, *Standard Specification for Fuel Oils* (No. 1); ASTM D1655, *Standard Specification for Aviation Turbine Fuels* (Jet A); or ASTM D2880, *Standard Specification for Gas Turbine Fuel Oils* (1GT).

Fuel Oil. Liquid fuels defined as Grades 2, 4, 5, and 6 in ASTM D396, *Standard Specification for Fuel Oils,* or Grade 2GT in ASTM D2880, *Standard Specification for Gas Turbine Fuel Oils.*

Fuel Trip. The automatic shutoff of a specific fuel as the result of an interlock or operator action.

Fuel-Rich. Indicates a ratio of air to fuel supplied to a burner that provides less than the minimum excess air needed for optimum combustion of the fuel.

Gas. See "LP-Gas" and "Natural Gas."

Heat Recovery Steam Generator (HRSG). A heat exchanger that uses a series of heat transfer sections (e.g., superheater, evaporator, and economizer) positioned in the exhaust gas flow of a combustion turbine to recover heat and supply a rated steam flow at a required temperature and pressure.

HRSG. See "Heat Recovery Steam Generator."

HRSG Control System. The group of control systems that regulates the HRSG process, including the combustion control but not the burner management.

HRSG Enclosure. All ductwork from the combustion turbine exhaust through the steam generator to the stack, including any bypass duct connection.

HRSG Purge. See "Purge, Combustion Turbine," "Purge, Duct Burner," and "Purge Rate."

HRSG System. The unit assembly from the combustion turbine inlet to the flue gas outlet to the atmosphere.

Igniter. A permanently installed device, removable for maintenance only, that provides proven ignition energy for light-off of the main burner.

Igniter, Class 1. An igniter applied to ignite the fuel input through the burner and to support ignition under any burner light-off or operating conditions. Its location and capacity are such that it provides sufficient ignition energy (generally in excess of 10 percent of full-load burner fuel input) at its associated burner to raise any credible combination of burner inputs of both fuel and air above the minimum ignition temperature.

Igniter, Class 2. An igniter applied to ignite the fuel input through the burner under prescribed light-off conditions. The range of capacity of such igniters generally is 4 percent to 10 percent of full-load burner fuel input.

Igniter, Class 3. A small igniter applied in particular to gas and oil burners to ignite the fuel input to the burner under prescribed light-off conditions. The capacity of such igniters generally does not exceed 4 percent of the full-load burner fuel input.

Igniter, Class 3 Special. A special Class 3 high energy electrical igniter capable of directly igniting the main burner fuel.

Initial Operation. The first coordinated operation of the combustion turbine and HRSG.

Interlock. A device or group of devices arranged to sense a limit or off-limit condition or improper sequence of events and to shut down the related equipment or to prevent proceeding in an improper sequence in order to avoid a hazardous condition.

JP4. See "Fuel, JP4."

Kerosene. See "Fuel, Kerosene."

Listed. Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Logic System. The decision-making and translation elements of the burner management system. A logic system provides outputs in a particular sequence in response to external inputs and internal logic.

(a) *Hardwired Systems.* Individual devices and interconnecting wiring.

(b) *Microprocessor-Based Systems.*

1. Computer hardware, power supplies, input/output devices, and the interconnections between these.

2. Operating system and logic software.

Low Water Cutout. A device arranged to effect a master fuel trip when the water level in the steam drum(s) falls to a predetermined low level.

LP-Gas. A liquefied gas composed of any of the following hydrocarbons or their mixtures: propane, propylene, normal butane, isobutane, and butylenes.

Master Fuel Trip. An event resulting in the rapid shutoff of all fuel to the duct burners, including igniters.

Master Fuel Trip Relay. An electromechanical relay(s) utilized to trip all required equipment simultaneously.

Monitor. To sense and indicate a condition without initiating automatic corrective action.

Natural Gas. A gaseous fuel consisting mostly of a mixture of organic compounds (normally methane, ethane, propane, and butane). The Btu value of natural gases varies from 700 Btu/ft^3 to 1500 Btu/ft^3 (26.1 MJ/m^3 to 55.9 MJ/m^3), with the majority averaging 1000 Btu/ft^3 (37.3 MJ/m^3).

Oil. See "Fuel Oil."

Open Flow Path. A continuous path for movement of an airstream through the exhaust to the stack.

Operating Range, Burner. The range between the maximum fuel input and the minimum fuel input within which the burner flame can be maintained in a continuous and stable manner.

Outlet Draft. The flue gas pressure at the outlet of the last convection pass of the steam generator.

Partial Loss of Flame. Loss of flame at any of the separate flame envelopes or burners while flame is maintained at any of the other flame envelopes or burners.

Prove. To establish by measurement or test the existence of a specified condition, such as flame, level, flow, pressure, or position.

Purge, Combustion Turbine. A flow of air at purge rate through the combustion turbine and the appropriate portion of the HRSG enclosure for a sufficient number of volume changes that effectively removes any gaseous or suspended combustibles and replaces them with the purging medium.

Purge, Duct Burner. A flow of combustion turbine exhaust gas or air at purge rate through the HRSG enclosure for a sufficient number of volume changes that effectively removes any gaseous or suspended combustibles and replaces them with the purging medium.

Purge Rate. A constant flow of purging medium at sufficient velocity to achieve a purge.

Reliability. The probability that a generating unit or system will perform for at least a given period of time where used under specified conditions.

Remote Operation. Control from a location removed from the combustion turbine and HRSG.

Repeatability. The ability of a device to maintain a constant set point characteristic.

Runback, Combustion Turbine. The controlled unloading of a combustion turbine to a level required by HRSG or other equipment control demands.

Scavenging. The procedure by which liquid fuel left in a burner or igniter after a shutdown is cleared by admitting steam or air through the burner passages, typically through a dedicated scavenging medium valve.

SCR (Selective Catalytic Reduction). A method of reducing NO_x in flue gas.

Separator, Filter, Scrubber. A device incorporated in the main fuel supply line that effectively separates foreign liquids or solids from the fuel.

Set Point. A predetermined value to which a device or system is adjusted and at which it shall be required to perform its intended function.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Shutdown, Controlled. The normal unloading and shutdown sequence of plant components based on the manufacturer's criteria.

Shutdown, Emergency. An event resulting in the rapid shutoff of all fuel to the combustion turbine along with a master fuel trip.

Stable Flame. A flame envelope that retains its continuity throughout the maximum rate of change within the operating range of the HRSG.

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements, which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an Appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Start-Up Combustion Control System. A control system used to regulate and maintain proper air/fuel ratio during the start-up period where the customary indexes, such as pressure, temperature, load, or flow, that motivate the normal automatic combustion control system are not available or suitable.

Steam Generator. A closed vessel in which water is converted to steam or steam is superheated or in which any combination thereof takes place.

Steam Generator Enclosure. The physical boundary for all steam generator pressure parts and the combustion process.

Supervise. To sense a condition needing attention and automatically initiate corrective action.

Supplementary Firing. The provision of duct burners in an HRSG to increase the temperature of the combustion turbine exhaust gases.

Unit. The confined spaces of the combustion turbine, the HRSG, and the associated ducts that convey the air and combustion gases from the air intake to the stack outlet.

Valve, Charging. A small valve bypassing the main safety shutoff valve used for charging the fuel headers and piping and for testing for leaks.

Valve, Check. A valve used to prevent reverse flow.

Valve, Flow Control. A valve capable of regulating quantity of throughput to a controlled range.

Valve, Safety Shutoff. A fast-closing valve that automatically and completely shuts off the fuel supply to main burners or igniters in response to a fuel trip.

Valve, Supervisory Shutoff. A manually operated shutoff valve with a means to provide a "valve closed" position signal.

Valve, Vent. A valve used to allow venting of air or gas from the system to the atmosphere.

Watch-Dog Timer, External. A timer external to a microprocessor-based control that is used to compare the microprocessor cycle timing against itself and that fails safely if the microprocessor timing stops or exceeds the watch-dog time interval.

Chapter 4 Project Coordination

4-1 General.

4-1.1 Project coordination, including proper integration of the various system components, shall be the responsibility of the owner or the owner's designated representative from system inception through commercial operation to enhance equipment reliability and personnel safety.

NOTE: An HRSG is a complex system, often involving numerous components, multiple steam pressure levels, emission control systems, and auxiliary, augmented air, or supplementary firing.

4-1.1.1 The ability of the combustion turbine to satisfy the flow requirements through the HRSG enclosure as required in Section 7-4 shall be considered in the basic design phase.

4-1.1.2 An HRSG system shall be designed to meet the user's specified modes of operation.

4-1.1.3 System components and control loops shall be compatible and capable of stable operation and control during both steady-state and transient conditions.

4-1.1.4 Control and protective systems and operating sequences shall prohibit the operators from bypassing interlocks.

Exception: As permitted by 2-4.1.3.

4-1.1.5 Training shall ensure operator understanding of the relationships between components; the proper start-up, operation, and shutdown procedures; and the significance of alarms and proper action in response to those alarms.

4-1.2 Explosions and fires have occurred in fuel-fired steam-generating systems as a result of incomplete functional designs. Investigations have revealed human error but often have overlooked the chain of events contributing to the operating error. Therefore, the design, installation, and functional objectives of the overall system components and their controls shall be integrated. Ergonomics and an environment conducive to efficient operator actions and decisions shall be provided.

4-1.3 The planning and engineering phases of plant design and construction shall be coordinated with operating personnel to ensure that operations important to safety can be achieved by qualified operators. Where this is not possible, the needs of operating personnel shall be considered and anticipated.

4-1.4 The proper operator functions, maintenance activities, and training shall be the responsibility of the operating company.

4-2 Project Inception. In the project inception phase, the following shall be accomplished to ensure a plant design that meets expected operating modes and reliability needs:

(a) Establishment of plant operating parameters;

(b) Identification of site-related constraints;

(c) Review of steam cycle, including generating a family of heat balance diagrams for the expected operating ranges and modes;

(d) Conceptualization of plant layout to provide for personnel safety, operability, and maintenance needs;

(e) Definition and verification of requirements of worst case operating transients, including start-ups;

(f) Definition of required test program;

(g) Definition of start-up criteria and goals; and

(h) Identification of the authority having jurisdiction. If multiple authorities having jurisdiction are identified, the scope of each authority having jurisdiction shall be defined.

4-3 Design.

4-3.1* The project approach shall include full evaluation of all systems and components to ensure compatibility, interface requirements, system dynamics, and the ability to meet all plant operating parameters.

NOTE: Safety in any plant is the direct result of an extensive up-front effort in the engineering, design, and selection of equipment for each individual application.

4-3.2* This evaluation shall consider the use of dynamic simulation or prior operating experience, or both, before equipment is selected.

4-3.3 Electrical area classifications shall be established by the owner or the owner's designated representative in conjunction with the HRSG system designer prior to commencing detailed design. (*See 5-6.4.*)

4-4 Construction and Installation. The constructor and owner/operator responsible for the erection and installation of the equipment shall verify that all equipment is properly installed and connected.

4-5 Initial Training. The training program shall be specific to the equipment being installed and all applicable design data shall be made available.

4-5.1 Operator Training. See also 8-2.1.

4-5.1.1 Prior to commissioning, a formal training program shall be established to prepare personnel to operate equipment safely and effectively.

4-5.1.2 Operator training shall include:

(a) Start-up procedures;

(b) Normal operating procedures;

(c) Normal shutdown procedures;

(d) Emergency shutdown procedures; and

(e) Control and safety system check-out and test procedures.

4-5.1.3 Where different modes of operation are possible, the procedures identified in 4-5.1.2 shall be prepared for each operating mode. Procedures also shall be prepared for switching from one mode to another.

4-5.2 Maintenance Training. See also 8-2.2.

4-5.2.1 A formal maintenance training program shall prepare personnel to perform any required maintenance tasks safely and effectively. This program shall consist of study or review of maintenance manuals, videotapes, and programmed instruction and testing, field training, and training by equipment manufacturers, among others.

4-5.2.2 Maintenance procedures shall be established to cover routine and special techniques. Any potential safety factors, such as temperature, dust, contaminated or oxygen-deficient atmosphere, internal pressures, and limited access or confined space conditions, shall be included.

4-5.2.3 Procedures shall be consistent with safety requirements and the manufacturer's recommendations.

4-6 Commissioning.

4-6.1 The HRSG system shall not be operated until safeguards have been tested and demonstrated to operate properly as a system. Any temporary procedures, interlocks, and instrumentation shall be reviewed by the owner or owner's agent, the engineering consultant, the equipment manufacturer, and the operating company, and agreement shall be reached on their suitability in advance of start-up. All temporary modifications shall be documented, and permanent resolutions shall be accomplished prior to commercial operation.

4-6.2 The design and function of all safety interlock systems and protective devices shall be reviewed by the organization having HRSG system design responsibility together with those who are to operate and maintain the systems and devices. After installation, coordinated tests of all systems shall be accomplished before initial operation.

4-6.3 The HRSG system shall not be released for commercial operation before the installation and check of the required safeguards and instrumentation system have been confirmed by those responsible for the design and commercial operation.

4-6.4 Documentation of the plant equipment, the system, and maintenance activities shall be updated to reflect changes in the status of equipment and operating procedures accurately.

Chapter 5 Equipment

5-1 General. Equipment required by this standard for safe operation of the HRSG system shall be approved (*see definition of "Approved" in Section 3-1*) or shall have a demonstrated history of satisfactory and reliable operation for the intended service.

NOTE: The use of listed equipment, where available for the intended service, should be considered.

5-2 Combustion Turbine.

5-2.1 Fuel Supply.

5-2.1.1 For fuel oil, two stop valves or equivalent valves in series, with proof of closure, shall be provided in the oil line to the combustion turbine.

CAUTION: Means shall be provided to prevent or relieve excess pressure between these valves.

5-2.1.2 For fuel gas, two stop valves or equivalent valves in series, with proof of closure, shall be provided in the gas line to the combustion turbine. An automatic vent valve shall be provided between the two valves.

5-2.2 Purge.

5-2.2.1 The combustion turbine shall have means for purging in accordance with Section 7-4.

Exception: In the event the combustion turbine cannot provide purge in accordance with Section 7-4, other means shall be provided.

5-2.2.2 During the purge sequence, means shall be provided to ensure that fuel does not enter the combustion turbine system downstream of the combustion turbine fuel stop valves.

NOTE: The volume between the combustion turbine stop valves should be minimized.

5-2.3 Interlocks.

5-2.3.1 Interlocks shall be provided to prevent starting the combustion turbine unless HRSG safety conditions are satisfied. Additional interlocks might be required for unusual intended plant operating scenarios. Typical permissives that shall be considered include:

(a) Water in drum(s) within defined start-up range;

(b) Feedwater supply system available to respond to demand;

(c) Pressure in steam or water spaces not high;

(d) Exit temperature of duct burner(s) not high;

(e) Position of stack closure (if provided) correct; and

(f) Pressure in duct system not high.

5-2.3.2 Signals shall be provided to the combustion turbine control system to initiate a change in combustion turbine operating mode if HRSG safety conditions deviate beyond preset acceptable safety limits. Typical HRSG conditions that warrant a combustion turbine operational response and their corresponding responses shall include the following:

Condition	Response
Water in drum(s) below minimum permitted level	Reduce load[1]
Gas pressure in combustion turbine exhaust plenum high	Trip combustion turbine
Position of stack closure (if provided) not correct	Trip combustion turbine

[1]Some steam drum and generating bank designs require a combustion turbine trip if water level falls below specified levels.

CAUTION: A combustion turbine trip is very costly in terms of its affect on combustion turbine life expectancy and shall be performed only under severe conditions that can result in a safety hazard or significant equipment damage.

5-2.4 Operating Interfaces.

5-2.4.1 The necessity for gradual loading and low-load hold/soak periods for the HRSG shall be evaluated for the following parameters:

(a) Tube and drum metal temperatures;

(b) Differential metal temperatures within a particular component (i.e., steam drum);

(c) Rate of change of critical temperatures;

(d) Drum water level.

5-2.4.2 In the event HRSG system conditions deviate beyond alarm set points to the interlock limit, the control system shall alarm the condition and initiate a duct burner trip as well as a combustion turbine runback to reduce thermal energy input to the HRSG to a safe level.

5-2.4.3 The control system or operator shall trip the combustion turbine in the case of an emergency that would lead to a safety hazard or catastrophic failure after the actions of 5-2.4.2 have been accomplished. (*See also 5-2.3.2.*)

5-2.4.4 Consideration shall be given to taking pre-emergency action automatically in the event tripping parameters deviate beyond alarm levels in order to minimize thermal stress duty cycles on the combustion turbine. Runback parameters shall be permitted to initiate from the HRSG or other plant subsystems.

5-3* HRSG Fuel-Burning System.

5-3.1 General.

5-3.1.1 The fuel-burning system shall contain the following subsystems, as applicable:

(a) Fuel supply;

(b) Main burner;

(c) Igniter;

(d) Atomizing media supply (if included); and

(e) Combustion products removal.

5-3.1.2 The fuel-burning system shall provide means for proper start-up, operation, and shutdown of the combustion process. This shall include appropriate openings and configurations in the component assemblies to allow suitable observation, measurement, and control of the combustion process.

5-3.1.3 Each igniter/burner element shall have a purged and cooled flame scanner port embodied in the design.

5-3.1.4 An observation port(s) shall be provided and conveniently located to allow visual inspection of the igniter and main burner flames.

5-3.2 Fuel Supply.

5-3.2.1 General.

5-3.2.1.1 The fuel supply equipment shall be sized and arranged to ensure a continuous fuel flow adequate for all operating requirements of the unit. This includes coordination of the main fuel control valve, burner safety shutoff valves, and associated piping volume to ensure against fuel pressure transients that might result in exceeding burner limits for stable flame as a result of placing burners in service or taking them out of service.

5-3.2.1.2 The fuel supply equipment shall be designed to inhibit contamination of the fuel. Convenient access to important fuel system components shall be provided. Drains shall be provided at low points in the piping.

5-3.2.1.3 The fuel supply equipment shall be capable of continuing the proper fuel flow during anticipated exhaust gas pressure pulsations at the burner.

5-3.2.1.4 The fuel supply equipment shall be designed with careful consideration of operating environment and ambient conditions, including severe external conditions such as fire or mechanical damage.

5-3.2.1.5 The requirements of the design shall facilitate good housekeeping practices.

5-3.2.1.6 Particular attention shall be given to the integrity of flexible hoses or swivel joints.

5-3.2.1.7 The fuel piping materials and system design shall be in accordance with ASME B31.1, *Power Piping*.

5-3.2.1.8 As much of the fuel supply subsystem as practical shall be located away from the burner front. A manual emergency shutoff valve shall be provided that is accessible in the event of fire in the HRSG area.

NOTE: Protection for burner front exposed equipment might justify installation of fire protection as indicated in NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants*.

5-3.2.2 Additional Requirements for Fuel Gas.

5-3.2.2.1 The portion of the fuel supply system upstream of the fuel control valve shall be arranged to prevent excessive fuel gas pressure in the fuel-burning system, even in the event of failure of the main supply constant fuel pressure regulator(s). Where full relieving capacity is not installed, the piping system shall be designed for the full supply pressure up to and including all individual burner and igniter safety shutoff valves.

NOTE: Usually this can be accomplished by providing full relieving capacity vented to a safe location.

5-3.2.2.2* Positive means to prevent leakage of fuel gas into an idle HRSG shall be provided. An atmospheric vent shall be installed between redundant shutoff valves in any header for main gas or igniter fuel supply.

5-3.2.2.3 Provisions shall be made in the gas piping to allow testing for leakage and subsequent repair. This shall include providing a permanent and ready means for making easy, accurate, periodic tightness tests of the main safety shutoff valves and individual burner safety shutoff valves.

5-3.2.2.4 The discharge from atmospheric vents shall be located so that there is no possibility of the discharged gas being drawn into the combustion turbine air intake, ventilating system, or windows of adjacent buildings and shall be extended sufficiently above the HRSG and adjacent structures so that gaseous discharge does not present a fire hazard.

5-3.2.2.4.1 Each header vent line shall be run independently.

5-3.2.2.4.2 The igniter vent subsystem shall be run independently of the burner vent subsystem.

5-3.2.2.4.3 There shall be no cross connection between venting systems of different steam generators.

5-3.2.2.5 All burner safety shutoff valves shall be located as close as practical to the burner to minimize the volume of fuel left in the burner lines located downstream of the valves.

5-3.2.3 Additional Requirements for Fuel Oil.

5-3.2.3.1 Fill and recirculation lines to storage tanks shall discharge below the liquid level to avoid free fall, which might generate static electrical charges as well as increase vaporization.

NOTE: See NFPA 77, *Recommended Practice on Static Electricity*, and API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*.

5-3.2.3.2 Adequate strainers, filters, traps, sumps, and other such items shall be provided to remove harmful contaminants where practical; materials not removed shall be accommodated by special operating and maintenance procedures.

NOTE: Contaminants in fuel oil might include salt, sand, sludge, water, and other abrasive or corrosive constituents. Some fuel oils contain waxy materials that precipitate out, clogging filters and other elements of the fuel system.

5-3.2.3.3 Special attention shall be given to the routes of piping, valve locations, and other such components to minimize exposure to high-temperature or low-temperature sources. Low temperature might increase viscosity, inhibit flow, or precipitate waxy materials. High temperatures might cause carbonization or excessive pressures and leakage due to fluid expansion in "trapped" sections of the system.

5-3.2.3.4 Means shall be provided to prevent or relieve excess pressure from expansion of entrapped oil in the fuel system.

5-3.2.3.5 Relief valve discharge passages, vents, and telltales shall be provided with suitable piping to allow safe discharge of oil or vapors. This piping might need to be heat traced.

5-3.2.3.6 All instruments and control piping and other small lines containing oil shall be rugged, capable of withstanding the expected range of external temperatures, suitably protected against damage, and maintained at the proper temperature. Interface fluids or sealing diaphragms shall be used where necessary.

5-3.2.3.7 Positive means to prevent leakage of oil into an idle HRSG shall be provided.

5-3.2.3.8* Provisions shall be made in the oil supply system to allow testing for leakage and subsequent repair.

5-3.2.3.9 Fuel oil shall be delivered to the burners at proper temperature and pressure, as recommended by the burner manufacturer, to ensure that the oil is at the viscosity necessary for proper atomization.

5-3.2.3.10 If heating of oil is necessary, it shall be accomplished without contamination or coking.

5-3.2.3.11 For heated systems, adequate recirculation provisions shall be incorporated for controlling the viscosity of the oil to the burners for initial light-off and for subsequent operation. These systems shall be designed and operated to prevent excessively hot oil from entering fuel oil pumps that could cause them to vapor-bind with subsequent interruption to the fuel oil supply.

5-3.2.3.12 Positive means shall be provided to prevent fuel oil from entering the burner header system through recirculating valves, particularly from the fuel supply system of other equipment.

NOTE: Check valves used for this function have not proven dependable in heavy oil service.

5-3.2.3.13 Atomizing media, where required, shall be supplied free of contaminants that could cause an interruption of service. In addition, adequate insulation and traps shall be included for steam atomizing to ensure the supply of dry atomizing steam to the burners.

5-3.2.3.14 The atomizing medium shall be provided and maintained at the pressure necessary for proper operation.

5-3.2.3.15 Provisions shall be made to ensure that fuel cannot enter the atomizing medium line at any time.

5-3.2.3.16 The atomizing subsystem shall be designed for convenient cleaning and maintenance.

5-3.2.3.17 All burner safety shutoff valves shall be located as close to the burner as practical to minimize the volume of oil that might be left downstream of the burner valve in the burner lines or that might flow by gravity into the HRSG on an emergency trip or burner shutdown.

5-3.3 Ignition.

5-3.3.1 The ignition subsystem shall be sized and arranged to ignite the main burner fuel input within the limitation of the igniter classification. Igniters are designated by use as Class 1, Class 2, or Class 3 as defined in Chapter 3. Igniters shall be tested to verify that they meet the requirements of the class specified in the design.

5-3.3.1.1 Class 1 igniters shall be permitted to operate as Class 2 or Class 3 igniters.

5-3.3.1.2 Class 2 Igniters.

5-3.3.1.2.1 Class 2 igniters shall be permitted to operate as Class 3 igniters.

5-3.3.1.2.2 Where Class 2 igniters are provided, the burner shall be operated under controlled conditions to limit the potential for abnormal operation, as well as to limit the charge of fuel into the duct in the event that ignition does not occur during light-off.

5-3.3.1.2.3 Class 2 igniters shall not be used to ignite the main fuel under uncontrolled or abnormal conditions.

5-3.3.1.2.4 Class 2 igniters shall not be used to extend the turndown range but shall be permitted to be used to support ignition under low-load or adverse operating conditions.

5-3.3.1.3 Class 3 Igniters.

5-3.3.1.3.1 Where Class 3 igniters are provided, the igniter shall be turned off when the trial for ignition period has expired.

5-3.3.1.3.2 Class 3 igniters shall not be used to support ignition nor to extend the burner turndown range.

5-3.3.1.3.3 Class 3 igniters shall not be used unless supervision of the individual main burner flame is provided.

Exception: The Class 3 special igniter shall be permitted to be used without supervision of the individual main burner flame while scavenging the main burner.

5-3.3.2 Permanently installed igniters shall be required, and they shall be supervised individually.

5-3.3.3 The ignition equipment shall be located in an appropriate environment with convenient access for maintenance.

5-3.3.4 All igniter safety shutoff valves shall be located close to igniters to minimize the volume of fuel that is downstream of the valves.

5-3.3.5 Igniter parts exposed to combustion turbine exhaust gas, radiation, or flame shall be designed and fabricated of materials to withstand the operating conditions.

5-3.3.6 Igniters shall be suitably shielded from the effects of the combustion turbine exhaust gas to ensure a stable flame under all operating conditions.

5-3.3.7 Ignition devices shall be removable for maintenance while the HRSG is in service.

CAUTION: Precautions shall be taken for personnel protection when removing such parts during operation, as they will be hot and hot gases will exit the opening left by the removed part.

5-3.3.8 Ignition transformers shall be housed in an enclosure complying with the relevant requirements of NFPA 70, *National Electrical Code®*, regarding electrical classification and environment and shall be bolted to the duct burner frame and adjacent to the igniter, thereby minimizing the length of high voltage cable.

5-3.3.9 The ignition transformer shall not be energized before the HRSG enclosure purge is completed. The ignition transformer shall be deenergized at the end of the igniter trial for ignition period.

5-3.4 Main Burner.

5-3.4.1 General.

5-3.4.1.1 Burner Elements. The burner elements shall be designed for operation with the fuel(s) specified. The burner shall be designed to produce a stable flame for its operating range.

5-3.4.1.2 Burner parts exposed to turbine exhaust gas, radiation, or flame shall be designed and fabricated of materials to withstand the operating conditions.

5-3.4.1.3 Provision shall be made for visual observation of the burner flame, including the ignition zone.

5-3.4.1.4 The burner equipment shall be located with convenient access to the burner components and hardware.

5-3.4.1.5 The main burner subsystem shall be designed so that the burner fuel inputs are supplied to the HRSG continuously and within their stable flame limits.

NOTE: Variations in burning characteristics of the fuel and the normal variations in fuel-handling and fuel-burning equipment introduce an uncertainty to the lower operating limits of the main fuel subsystem in any given HRSG design. In these circumstances, Class 1 or Class 2 igniters, as demonstrated by test, can be used to maintain stable flame.

5-3.4.1.6 The limits of stable flame for each burner subsystem producing a separate flame envelope shall be determined by tests without the ignition subsystem in service. These tests shall verify that transients generated in the fuel and combustion turbine exhaust gas subsystems or maldistribution of the combustion turbine exhaust gas do not adversely affect the burners in operation. These tests shall include the expected range of available fuels.

NOTE: Such transients are generated by burner shutoff valves, dampers, and other components that operate at speeds faster than the speed of response of other components in the system.

Exception: The requirement to test without the ignition subsystem in service shall not apply to burner systems that require the igniter to be in service any time the burner is being operated.

5-3.4.1.7 Where Class 1 or Class 2 igniters are used, the tests in 5-3.4.1.6 also shall be performed with the ignition subsystem in service to verify that the igniters furnished meet the requirements of the class specified in the design. Any resulting extended turndown range shall be available only when Class 1 igniters are in service and flame is proven.

5-3.4.2 Additional Burner Requirements for Fuel Oil.

5-3.4.2.1 Provisions shall be made for cleaning of the burner nozzle and tip.

5-3.4.2.2 Provisions shall be included for clearing (scavenging) the passages of an oil burner into the HRSG with that burner's igniter in service. If the igniter is not operational, the burner shall be removed for clearing.

5-4* HRSG Enclosure.

5-4.1* The HRSG, ducts, and stack shall be sized and arranged to maintain acceptable combustion turbine exhaust gas backpressure and to remove the products of combustion at the same rate that they are generated by the fuel-burning process during operation of the unit.

5-4.2 The HRSG and ducts shall be capable of withstanding a transient pressure determined by the HRSG system designer without permanent deformation due to yield or buckling of any support member.

5-4.3* Proper expansion provision shall be made for the movement of the turbine exhaust duct and the HRSG ducts. Any expansion joints so provided shall withstand at least the highest design pressure for which either duct is designed.

5-4.4* Convenient access and drain openings shall be provided.

5-4.5 The HRSG ducts shall be designed so that they cannot contribute to flame pulsations.

5-4.6 Components common to more than one steam generator shall not limit the rate of removal of products of combustion.

5-4.7 The HRSG ducting between the combustion turbine outlet and the duct burners shall be designed to provide proper distribution of combustion turbine exhaust gas as required by the burner manufacturer for stable burner operation.

5-4.8 All HRSG units that utilize liquid fuels shall have a duct design that meets the criteria of 5-4.8.1 through 5-4.8.3.

5-4.8.1* All low points shall have sufficient slopes to ensure that no dead pockets exist in the bottom of the ducts at other than a designed low point.

5-4.8.2* Drains shall be installed, as appropriate, at the low points to facilitate clearing fuel from the HRSG enclosure.

5-4.8.3 Provisions shall be included in the design and operation to prevent liquid fuels from being absorbed into the insulation that could result in a fire or an explosion.

5-5* Selective Catalytic Reduction.

5-5.1 Where selective catalytic reduction (SCR) systems are selected for NO_x emission control, they shall be integrated into the HRSG design to operate in the flue gas temperature range required.

5-5.2 Areas in which either anhydrous or aqueous ammonia is stored or piped shall be ventilated adequately to preclude toxic or flammable concentrations.

5-5.3 Anhydrous or aqueous ammonia vessels shall be designed to contain their contents at expected elevated ambient temperatures. Overpressure relief valves vented to a safe location shall be provided.

CAUTION: Precautions shall be taken when selecting a storage area for ammonia, as the pressure in storage vessels can rise significantly when exposed to elevated temperatures.

5-6 Electrical.

5-6.1 Electrical equipment shall be protected against transient voltages according to the manufacturer's specification. As a minimum, the system shall function at voltages up to 10 percent above the nominally rated voltage and down to 10 percent below the nominally rated voltage.

5-6.2 All wiring shall comply with the requirements of NFPA 70, *National Electrical Code.*

5-6.3 All high voltage equipment shall be marked in accordance with the requirements of NFPA 70, *National Electrical Code.*

5-6.4 Where an area is identified as a hazardous location under NFPA 70, *National Electrical Code*, Article 500, the type of equipment enclosure and the wiring methods to be used are specified by that code and shall be followed.

NOTE: For guidance in determining area classification, see NFPA 497A, *Recommended Practice for Classification of*

Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas; NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*; NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*; NFPA 70, *National Electrical Code*, Article 500; and API RP 500A, *Classification of Locations for Electrical Installations in Petroleum Refineries*.

5-6.5 The electrical supply to the burner management system and important subcircuits shall be protected by circuit breakers or fuses.

5-6.6 Upon initiation of a master fuel trip, failure of an electrical power supply shall not impede the orderly and rapid shutdown process.

Chapter 6* Controls, Monitoring, Alarms, and Interlocks

6-1 Control Functions.

6-1.1 General.

6-1.1.1 A single component failure shall not cause loss of the control system's critical functions identified in 6-4.3.

6-1.1.2 Equipment shall be designed and procedures established to permit on-line maintenance of the control equipment. Proper lockout or tagout procedures shall be followed.

6-1.1.3 Procedures for calibrating and testing of controls and interlocks shall be provided.

6-1.2 Fuel Control.

6-1.2.1 Fuel input shall be controlled to maintain stable firing conditions. Remote manual operation shall be permitted.

6-1.2.2 Minimum and maximum limits on the fuel input shall be established to prevent fuel flow beyond the stable limits of the fuel-burning system.

6-1.3 Feedwater/Drum Level Control. The water level in each drum shall be maintained automatically. Remote manual operation of the feedwater control device shall be available.

6-2 Monitoring.

6-2.1 Information about significant operating events shall be displayed to permit the operator to make a rapid evaluation of the operating situation.

6-2.2 Recording or trend displays of critical parameters taken at intervals no greater than 5 seconds shall be available to the operator at the operator location. (*See 6-2.3.*)

6-2.2.1 Where accessed through a CRT display in response to an alarm condition, the trend displays shall appear in not more than 5 seconds.

6-2.2.2 Where CRT trend displays are used, the displays shall provide data that is current to within the prior 30 minutes at minimum, and the data provided shall have been stored at intervals of not more than 1 second.

6-2.3 The following HRSG parameters shall be continuously recorded on charts, or the data shall be logged and trended in accordance with 6-2.2.1 and 6-2.2.2:

(a) Water level in each steam drum;

(b) Fuel pressure at the duct burner(s);

(c) Steam pressure at each pressure level;

(d) Duct burner exit temperature before the first tube bank;

(e) Atomizing medium pressure (for oil only);

(f) Gas temperature upstream of the emissions control catalyst(s); and

(g) HRSG flue gas exit temperature.

6-2.4 Consideration shall be given to monitoring the following additional HRSG parameters:

(a) Fuel flow;

(b) Fuel supply header pressure;

(c) Feedwater pressure at each pressure level;

(d) Feedwater flow at each pressure level;

(e) Economizer inlet water temperature;

(f) Economizer outlet water temperature;

(g) Steam temperature at each level;

(h) Steam flow at each pressure level; and

(i) Oxygen in flue gas at HRSG outlet.

6-3 Alarms.

6-3.1 Functional Requirements.

6-3.1.1 The functional requirement of any alarm system is to bring a specific abnormal condition to the attention of the operator.

6-3.1.2 Alarms shall be provided to indicate equipment malfunction, hazardous conditions, misoperation, or abnormal conditions that might lead to impending or immediate hazards.

6-3.1.3 The design shall make it difficult to manually defeat the alarm.

6-3.1.4 Where equipment malfunction makes it necessary to defeat an alarm, it shall be done by authorized personnel, and the alarm shall be tagged as inoperative.

6-3.1.5 Alarm systems shall be designed so that, for the alarms required by 6-3.2, the operator receives audible as well as visual signals indicating an abnormal condition. The operator shall be permitted to silence the audible signal.

6-3.2 Required Alarms.

6-3.2.1 General. The alarms indicated in 6-3.2.1.2 through 6-3.2.1.9 shall be required.

6-3.2.1.1 All interlock trips shall be alarmed individually.

6-3.2.1.2 HRSG Steam Pressure (High). High HRSG steam pressure shall be measured at each steam pressure level. It shall warn the operator of a pressure in excess of normal operation.

6-3.2.1.3 Loss of Interlock Power. Loss of interlock power shall be sensed and alarmed and shall include all sources of power required to complete interlock functions. For example, if both a 125-V DC electric circuit and a compressed air circuit are required for an interlock scheme, then loss of either shall be annunciated.

6-3.2.1.4 Loss of Control Power. Loss of control power shall be sensed and alarmed to include any sources of power for the control systems. For example, if both a 125-V dc electric circuit and a compressed air circuit are required for control, then loss of either shall be annunciated.

6-3.2.1.5 Burner Valves Not Closed. The closed position of individual burner safety shutoff valves shall be monitored, and failure of any valve to close following a trip shall be alarmed.

6-3.2.1.6 Drum Water Level (Low). The water level in the steam generator drums shall be monitored and alarmed when the level in any drum drops below the normal operating range.

6-3.2.1.7 Loss of Electrical Generator.

6-3.2.1.8 Duct Firing Temperature (High).

6-3.2.1.9 Scanner Cooling Air Pressure (Low).

6-3.2.2 Additional Alarms for Fuel Gas.

6-3.2.2.1 Fuel Gas Supply Pressure (High and Low). The gas pressure supplied to the plant shall be monitored at a point as far upstream of the final constant fuel pressure regulator, main fuel control, and main safety shutoff valves as practicable. This is to warn the operator of unusual pressure conditions that might result in damage to equipment or indicate a complete loss of gas supply.

6-3.2.2.2 Fuel Gas Burner Header Pressure (High and Low). The burner header gas pressure shall be monitored as close to the burners as possible in order to warn the operator of abnormal fuel pressures in advance of duct burner trip conditions.

6-3.2.2.3 Fuel Gas Meter Pressure (High and Low). The pressure at the fuel gas meter shall be monitored at the upstream tap if the fuel gas flow meter is part of the combustion control system and is not pressure compensated. This shall warn the operator if significant error is present in the flow signal to the control system.

6-3.2.2.4 Ignition Fuel Header Pressure (High and Low). The ignition fuel header pressure for Class 1 and Class 2 igniters shall be monitored as close to the burners as possible in order to warn the operator of high or low pressure in advance of conditions that lead to a trip.

6-3.2.3 Additional Alarms for Fuel Oil.

6-3.2.3.1 Main Oil Supply Pressure (Low). The oil supply pressure shall be monitored at a point as far upstream of the main fuel control and safety shutoff valves as practicable. This is to warn the operator of unusual pressure conditions that might result in damage to equipment or to indicate a complete loss of supply.

6-3.2.3.2 Fuel Oil Burner Header Pressure (Low). The burner header oil pressure shall be monitored as close to the burners as possible in order to warn the operator of low pressure in advance of conditions that lead to a trip.

6-3.2.3.3 Atomizing Medium Pressure (Low). An alarm shall be provided to warn that the atomizing medium pressure is outside of normal operating range and that poor oil atomization might result.

6-3.2.3.4 Fuel Oil Temperature (Low) or Viscosity (High). For heated fuel oils, an alarm shall be provided to warn that the fuel oil temperature is below, or the viscosity is above, that necessary for proper atomization.

6-4 Interlocks.

6-4.1 Functional Requirements.

6-4.1.1 The basic requirements of an interlock system for an HRSG are that it protect personnel from injury and protect the equipment from damage. The interlock system functions to protect against improper HRSG operation by limiting action to a prescribed operating sequence or by initiating trip devices when approaching an unstable or undesirable operating condition.

> **CAUTION:** It is possible to achieve conditions conducive to an explosion without their detection by any of the mandatory automatic trip devices, even though such devices are properly adjusted and maintained. Therefore, operating personnel shall be made aware of the limitations of the interlock system.

6-4.1.2 Periodic testing and maintenance shall be performed to keep the interlock system functioning properly.

6-4.1.3 Whenever a safety interlock device has been removed from service temporarily for maintenance, testing, or repair, this action shall be noted in the log and annunciated, if practical. Other means shall be substituted to supervise this interlock function.

6-4.1.4 The design of an interlock system shall include the following fundamentals:

(a) Supervision of the starting procedure and operation to ensure proper operating practices and sequences;

(b) Tripping of the minimum amount of equipment in the proper sequence when the safety of personnel or equipment is jeopardized;

(c) Indication of the initiating cause of the trip and prevention of the start of any portion of the process until proper conditions are established;

(d) Coordination of the necessary trip devices into an integrated system;

(e) Provision of sufficient instrumentation to enable the operator to complete the proper operating sequence in cases where automatic equipment is not available to accomplish the intended function;

(f) The incorporation in the design of as much flexibility with respect to alternate modes of operation as is consistent with good operating practice;

(g) Provision of proper preventive maintenance;

(h) Interlocks that shall not require any deliberate "defeating" in order to start or operate equipment;

(i) The independence of mandatory master fuel trip sensing elements and circuits from all other control elements and circuits; and

Exception: Individual burner flame detectors also shall be permitted to be used for initiating duct burner master fuel trip systems.

(j) Prevention of the misoperation of the interlock system due to an interruption or restoration of the interlock energy supply.

6-4.1.5 Interlock functions shall be initiated by one or more of the following:

(a) Switches independent of control functions and signals;

(b) An analog signal, provided two analog signals are available with a divergence alarm; or

(c) Three analog signals employing an auctioneering system and a divergence alarm, or other appropriate fault diagnostic alarm.

6-4.2 Flame Detection.

6-4.2.1 Each burner element or zone shall be supervised individually. Upon detection of loss of flame, the associated individual burner safety shutoff valves shall close automatically.

6-4.2.1.1 Where two flame detectors are fitted to each firing element, the flame scanners shall be arranged to alarm on loss of flame from one scanner and to trip the system on loss of flame from two scanners. With one detector out of service, the remaining detector shall trip the system upon loss of flame detection.

6-4.2.1.2 Where Class 1 igniters are provided, the main burner flame shall be proven either by the flame scanner or by proving the igniter. At least one flame detector shall be provided for each burner to detect the burner flame or igniter flame where a Class 1 igniter is provided.

6-4.2.1.3 Burners with Class 2 igniters shall have at least two flame detectors. One detector shall detect the main burner flame and shall not detect the igniter flame. The second detector shall detect the igniter flame during prescribed light-off conditions.

6-4.2.1.4 Burners with Class 3 igniters shall have at least one flame detector. The detector shall detect the igniter flame. It also shall detect the main burner flame after the igniter is removed from service at the end of the main burner trial for ignition.

6-4.2.1.5 Where a self-checking flame scanner is provided to each burner, a burner trip shall occur if the scanner exhibits a self-check fault. Where two self-checking flame scanners are fitted to each burner, the flame scanners shall alarm on loss of flame or the self-check failure of one scanner and shall trip the burner on loss of flame or the self-check failure of two scanners. With one detector out of service, the remaining detector shall trip the burner upon loss of flame or self-check failure.

6-4.2.2 Where a hazardous condition results from loss of flame in more than one burner element or zone, a master fuel trip shall be initiated.

6-4.2.3 It is recognized that any fuel input that does not ignite and burn creates a hazard. Regardless of the number or pattern of flame loss indications used for tripping, flame loss indication on a firing element shall initiate an alarm that warns the operator of a potential hazard.

6-4.2.4 Field testing shall be required to validate basic functions of flame tripping. These tests shall be performed on representative units. The results of these tests might be applied to other units of similar size and arrangements, including firing elements/nozzles of essentially the same capacity that use similar fuels. These tests shall not be used to replace an acceptance test related to proof of design, function, and components.

6-4.2.5 Flame detector sighting shall be considered in the initial duct burner design. Field tests shall be performed to establish optimum sighting angles of firing elements or igniters and also to check the angular range of the flame detector in relation to the firing elements or igniters.

6-4.3 Duct Burner Master Fuel Trip. A duct burner master fuel trip shall be initiated by the following conditions:

(a) Low fuel pressure;

(b) Total combustion turbine exhaust flow that drops below the minimum required for safe operation of the duct burner as specified by the burner manufacturer or as proven by trial; it shall be permitted to infer this flow from the operating status of the combustion turbine;

(c) Combustion turbine trip;

(d) Loss of all burner flame;

(e) Partial loss of flame sufficient to introduce a hazardous accumulation of unburned fuel;

(f) Closing of last individual burner safety shutoff valve;

(g) High fuel pressure, if a pressure above the operating limits of the burner(s) can occur;

(h) Low water level on high pressure section of HRSG;

(i) Loss of energy supply for boiler control, burner management, or interlock system;

(j) Atomizing media supply pressure low; or

(k) Burner management system malfunction detected.

6-5 Burner Management System Logic. This section provides requirements for the use of logic systems in burner management.

6-5.1 A single failure in the burner management system shall not prevent a required shutdown.

NOTE: Some items are not applicable to specific types of logic systems (e.g., relay).

6-5.2 The logic system designer shall recognize the failure modes of components when considering the design application of the system. As a minimum, the following failures shall be evaluated and addressed:

(a) Interruptions, excursions, dips, recoveries, transients, and partial loss of power;

(b) Memory corruption and losses;

(c) Information transfer corruption and losses;

(d) Inputs and outputs that read "fail on" or "fail off";

(e) Signals unreadable or not being read;

(f) Addressing errors;

(g) Processor faults; and

(h) Common mode failures.

6-5.3 Diagnostics shall be included in the design to monitor processor logic function.

6-5.4 Logic failure shall not preclude proper operator intervention.

6-5.5 Logic shall be protected from unauthorized changes. A written procedure shall be provided to control and document authorized upgrades, additions, and deletions.

6-5.6 Logic shall not be changed when the associated equipment is in operation.

6-5.7 System response time (throughput) shall be sufficiently short to prevent negative effects on the application.

6-5.8 Noise immunity shall be adequate to prevent false operation.

6-5.9 No single component failure within the logic system shall prevent a mandatory duct burner fuel trip.

6-5.10 The operator shall be provided with a dedicated manual switch(es) that shall activate the master fuel trip relay independently and directly.

6-5.11 No momentary contact or automatic resetting device, control, or switch that can cause chattering or cycling of the safety shutoff valves shall be installed in the wiring between the load side (terminal) of the primary or programming control and the main or ignition fuel valves.

6-5.12 Requirements for Independence.

6-5.12.1 The logic system performing the safety functions for burner management shall not be combined with any other logic system.

6-5.12.2 This logic system shall be physically separate and visually identifiable.

6-5.12.3 These burner management safety functions shall include purge interlocks and timing, mandatory safety shutdowns, trial timing for ignition, and flame monitoring.

6-5.13 Software shall be maintained either in some form of nonvolatile storage or other memory that retains information on the loss of system power.

6-5.14 Application software and input/output devices that support safety logic shall be physically separate from all other software and input/output devices.

6-5.15 System operation shall be verified for compliance with the standard whenever a controller is replaced, repaired, or updated.

6-5.16 Documentation shall be provided to the owner and operator verifying that all safety devices and logic meet the requirements of the application. Functional testing (simulation) of the system shall be performed before it is put into operation.

6-5.17 Programmable logic controllers, if used, shall be monitored by external watch-dog timers. If a timer trips, a duct burner trip then shall occur.

6-6 Operator Interface.

6-6.1 Alarms and indicators shall be grouped operationally and shall be visible to the operator to allow rapid access to operational devices.

6-6.2 All emergency alarm indicators, push buttons, and selector switches shall be readily visible to the operator and shall be labeled clearly. They shall be protected to avoid inadvertent actuation.

6-6.3 All control functions shall be grouped for easy access and in relatively close proximity to their associated alarm and indication devices.

6-6.4* Where CRT displays are used, data shall be displayed on monitor screens in a logical, operational grouping to minimize the number of keystroke operations needed to respond to system upsets. Alarm functions shall be prioritized to appear on the monitor screen upon being sensed, regardless of any information already displayed.

6-6.5 Personnel shall be trained to understand and interact with the control systems.

Chapter 7 Fuel Gas or Fuel Oil Systems

7-1 General.

7-1.1* This chapter contains requirements for burning fuel gas or fuel oil in duct burners. These include certain interlocks for preventing improper action, certain safety trips and flame supervisions, and an indication of the status of the start-up sequence.

7-1.2 This chapter provides minimum standards for design, installation, and operation of duct burners in the exhaust ductwork of a combustion turbine coupled to an HRSG. No specific degree of automation beyond the minimum specified safeguards is defined or required, as this is subject to many factors such as, but not limited to, physical size of the unit, use of the central control room, degree of reliability required, and availability of experienced operating personnel. All devices required in the text shall be provided. The requirements of the operating system that shall be used with these limitations are as follows:

(a) A trained operator shall be available at an appropriate location to take the required safety actions;

(b) The start-up of the burner as a first-time function shall be accomplished by an operator at the burner location who has a direct view of the burner. Recycling of the burner in response to steam demand shall be permitted to be an automatic sequence, provided the combustion turbine has not tripped; and

(c) Suitable equipment shall be provided to control HRSG inputs and their rate of relative change within the limits of stable flame throughout the full operating range.

7-2 General Operating Requirements.

7-2.1 Prior to starting a unit, action shall be taken to prevent fuel from entering the HRSG system.

7-2.2 The associated igniter for a burner always shall be used unless the burner is specifically designed to be lit from an adjacent burner. Burners shall not be lit from any hot surface.

7-2.3 Where operating at low capacity, burner fuel pressure shall be maintained above the minimum by reducing the number of burners in service as necessary.

7-2.4 Gas. Before maintenance is performed on the gas header, it shall be purged. (*See A-7-1.1.*)

7-2.5 Oil. Before maintenance is performed on the oil header, it shall be drained and purged as necessary. (*See A-7-1.1.*)

7-2.6 Oil — Scavenging of Oil Burner Passages.

7-2.6.1 Oil burner passages shall not be scavenged into a nonoperating HRSG. Combustion turbine exhaust flow shall be functioning and shall be maintained during the scavenging process.

7-2.6.2 Igniters, with ignition established, shall be in service when scavenging oil passages into the HRSG.

7-2.7 Sequencing.

7-2.7.1 Sequencing shall be required to ensure that operating events occur in proper order. Written procedures shall be provided to sequence the start-up and shutdown of the entire unit (combustion turbine and HRSG) properly. Sequencing also shall be utilized when removing burners from operation or adding burners to operation.

7-2.7.2 The starting and shutdown sequence outlined in this chapter shall be followed.

NOTE: This sequence provides a continuous airflow or flue gas flow through the HRSG at a rate that is at least the rate that existed during the purge operation. The objective of this practice is to ensure minimum velocities through the unit to prevent hazardous accumulations of unburned fuel.

7-2.7.3 Burners shall not be placed in service or removed in a random pattern but shall be placed in service or removed in a sequence specified by operating instructions and verified by actual experience with the unit in order to minimize laning or stratification of fuel or combustion products. Burners shall be placed in service as required, with fuel flows that ensure proper light-off.

NOTE: Automatic start systems may be permitted to establish igniter flame on multiple burner elements simultaneously with proper supervision. Similarly, main burner elements may be permitted to be configured to operate as one with proper supervision.

7-2.7.4 If the fuel pressure at the burner header is used as a guide in maintaining the necessary fuel flow per burner, it shall be maintained automatically within prescribed limits as additional burners are placed in service.

7-2.7.5 Duct burners shall be operated in accordance with the manufacturer's specifications and operating procedures.

7-2.7.6 This procedure shall incorporate the following operating objectives:

(a) The purge shall be completed in accordance with Sections 7-4 and 7-5; and

(b) No light-off of the duct burner(s) shall occur until after the combustion turbine has established stable operation with an exhaust gas flow not less than that necessary for duct burner operation.

7-2.7.7 Each unit shall be tested during commissioning to determine whether any modifications to the basic procedures are needed to obtain satisfactory ignition and system operation. However, the number of equipment manipulations shall be minimized.

7-2.7.8 The unit shall be operated within the specified parameters. Any modifications or deviations shall be made only after the need for such changes has been determined by operating experience and system review.

7-3 Cold Start Preparation. Preparation for starting shall include a thorough inspection, particularly for the following:

(a) Unit in good repair and free of foreign material;

(b) *Oil.* Unit inspected for accumulated fuel oil, with draining and cleaning performed, as necessary;

(c) All personnel evacuated from the unit and associated equipment and all access and inspection doors closed;

(d) All safety shutoff valves proved closed and all ignition sources deenergized;

(e) *Gas.* Fuel gas system vents open and venting to a safe outside location; fuel gas lines drained of condensate;

(f) *Oil.* Circulating valves open to provide and maintain oil flow in the burner headers;

(g) Proper drum water levels established in natural and forced circulation HRSGs and flow established in forced circulation HRSGs;

(h) Burner elements and igniters positioned in accordance with manufacturer's specification;

(i) Energy supplied to control systems and to safety interlocks;

(j) Meters or gauges indicating fuel header pressure to the unit;

(k) Instrumentation tested and functional;

(l) A complete functional check of the safety interlocks performed after an overhaul or other significant maintenance; and

(m) Verification of an open flow path from the inlet of the combustion turbine through the HRSG unit to the stack discharge.

7-4 Combustion Turbine Purge and Light-Off.

7-4.1 The purge of the combustion turbine shall be in accordance with the manufacturer's instructions and the requirements of 7-4.2 and 7-4.3.

NOTE: A complete purge of the combustion turbine and portions of the HRSG enclosure is necessary before light-off of the combustion turbine. The objective of this practice is to remove potential accumulations of hazardous unburned fuel from the volume defined in 7-4.2.1 that could be ignited by light-off of the combustion turbine.

7-4.2 Initial Combustion Turbine Purge and Light-Off.

7-4.2.1 Purge prior to the light-off of the combustion turbine shall be accomplished by at least five volume changes and for a duration of not less than 5 minutes. This volume shall be calculated based on the following:

(a) The combustion turbine operating at full load with no supplementary HRSG firing; and

(b) The volume from the combustion turbine inlet to the portion of the HRSG where the combustion turbine exhaust gas temperature is reduced to at least 100°F (56°C) below the lowest autoignition temperature of the fuel(s) for which the system has been designed. However, in no case shall this volume be less than the volume of the HRSG enclosure between the combustion turbine outlet and the outlet of the first evaporator section in the HRSG.

7-4.2.2 During the purge of the combustion turbine, a flow rate as near as possible to 25 percent, but not less than 15 percent, of full-load mass airflow shall be provided through the HRSG enclosure.

7-4.2.3 In the event that the combustion turbine cannot meet the requirements of 7-4.2.2, alternative or supplementary means to satisfy the flow requirements through the HRSG enclosure shall be provided.

7-4.3 Failure to Start. On failure to start, retrial of the combustion turbine start shall be permitted following a repurge in accordance with 7-4.2. In the case of liquid fuel, verification also shall be made that the duct low point(s) is cleared of combustibles. (*See 5-4.8.*)

> **CAUTION:** Excessive retries shall be avoided. Where operating experience indicates there are problems in combustion turbine light-off, the light-off attempts shall be terminated and the cause investigated and corrected.

7-4.3.1 Where firing any liquid fuel or any gas that is heavier than air, verification shall be made that the duct low point(s) is cleared of combustibles. This shall be accomplished by one of the following methods:

(a) For a system firing any liquid fuel, the drains shall be checked to verify that they are clear and that no fuel is present (*see 5-4.8*); or

(b) For a system firing any gas that is heavier than air, the vents shall be checked to verify that no combustible gas is present. (*See 5-4.8.*)

7-4.3.2 The second trial to start the combustion turbine with the same or alternate fuel shall be permitted following a repurge in accordance with 7-4.2.

7-4.3.3 Subsequent trials to start the combustion turbine with the same or alternate fuel shall be permitted following a repurge in accordance with 7-4.2 and after proving that combustibles have been removed. This verification shall be accomplished using a combustibles analyzer.

> **CAUTION 1:** Stratification of gases shall be considered where analyzing for combustibles.

> **CAUTION 2:** Excessive retries shall be avoided. Where operating experience indicates there are problems in combustion turbine light-off, the light-off attempts shall be terminated and the cause investigated and corrected.

7-4.4 After completing the purge, the airflow through the combustion turbine shall be permitted to be dropped below the purge rate if required by the design to accomplish combustion turbine ignition.

7-4.5 After successful light-off of the combustion turbine, the combustion turbine shall be brought to speed and loaded as necessary to meet system demands.

> NOTE: The loading of the combustion turbine might be restricted by HRSG parameters.

7-5 Duct Burner Purge and Light-Off.

7-5.1 The duct burner purge shall be accomplished with a flow utilizing air or combustion turbine exhaust at not less than 25 percent of full-load mass flow rate or the minimum flow necessary for operation of the duct burners, whichever is greater.

7-5.2 The duct burner purge shall accomplish at least eight volume changes of the HRSG enclosure after combustion turbine exhaust flow in accordance with 7-5.1 has been achieved.

> NOTE: Purge prior to light-off of the combustion turbine should not be considered a duct burner purge unless the requirements of 7-5.1 and 7-5.2 have been satisfied.

7-5.3 A duct burner trip or failure to light off duct burners successfully shall require a repurge in accordance with 7-5.1 and 7-5.2 prior to attempting a relight.

7-5.4 Duct Burner. A duct burner purge shall be considered to have been achieved, provided the duct burner purge rate is maintained and all duct burner purge requirements have been satisfied. The duct burner shall be permitted to be lit, or a normal shutdown made, provided that credit for the purge is maintained. Failure of the duct burner purge rate to be maintained or failure to meet any duct burner purge requirement shall require a repurge in accordance with 7-5.1 and 7-5.2.

7-5.4.1 Testing igniters for duct burners shall be conducted in accordance with the following:

(a) A complete, periodic, operational test of each igniter shall be made. The frequency of testing depends on the design and operation history of each individual HRSG and ignition system. As a minimum, the test shall be made during each start-up following an overhaul or other significant maintenance.

> NOTE: The importance of reliable igniters and ignition systems cannot be overemphasized.

(b) Individual igniters or groups of igniters also shall be permitted to be tested while the unit is in service. Such tests shall be made with no main fuel present in the igniter's associated burner.

7-5.4.2 Starting Sequence.

7-5.4.2.1* The operating sequences described in 7-5.4.2 assume the use of multiple element duct burners operated independently of each other. For installations with a duct burner (single element or multiple element) operated as a single unit, procedures similar to those outlined in 7-5.4.2 shall be followed.

Exception: The procedures of 7-5.4.2 shall not apply to sequences unique to multiple burner operations.

> NOTE: For typical fuel supply systems for duct burners that operate as a single unit, see Figures A-7-5.4.2.1(a) through (d).

7-5.4.2.2* These starting sequences shall be performed in the following order, consistent with the manufacturer's instructions:

> NOTE: The sequences are based on the typical fuel supply systems shown in Figures A-7-5.4.2.2(a) through (f).

(a) All duct burner main fuel safety shutoff valves shall be proven to be closed. In addition, all duct burner igniter fuel safety shutoff valves shall be proven to be closed.

(b) The main fuel header and the igniter fuel header shall be pressurized up to the individual main burner and igniter safety shutoff valves in accordance with established operating procedures.

(c) The first individual igniter safety shutoff valve shall be opened, and the ignition transformer shall be energized. If flame on the first igniter is not established within 10 seconds, the individual igniter safety shutoff valve shall be closed. The cause of failure to ignite shall be determined and corrected. With turbine exhaust flow maintained, repurge shall not be required, but at least 1 minute shall elapse before attempting a retrial of this or any other igniter.

(d) The main fuel control valve shall be set to the burner light-off position.

(e) The first individual main burner safety shutoff valve shall be opened. If the main burner flame is not proven within 5 seconds after main fuel enters the duct, a duct burner master fuel trip shall occur.

(f) After each stable main burner flame is established, the igniter shall be shut off unless classified as Class 1 or Class 2. The stability of the main burner flame shall be verified.

(g) The associated igniter for a burner always shall be used to light the burner unless the burner is specifically designed to be lit from an adjacent burner. Burners shall not be lit from any hot surface.

(h) Second or succeeding igniters shall be lit in accordance with 7-5.4.2.2(c). If the second or succeeding burner igniter does not light off within 10 seconds after its individual igniter safety shutoff valve has been opened, the individual igniter safety shutoff valve shall close. The cause for failure to light shall be determined and corrected. At least 1 minute shall elapse before the next light-off is attempted.

(i) Second or succeeding burners shall be lit in accordance with 7-5.4.2.2(e). If the second or succeeding main burner flame is not established, the individual burner safety shutoff valve and individual igniter safety shutoff valve shall close. The cause for failure to ignite shall be determined and corrected. At least 1 minute shall elapse before the next light-off is attempted.

(j) After each successive burner light-off, the operator shall verify the flame stability of all operating burners.

7-6 Normal Operation.

7-6.1 The HRSG steaming rate shall be regulated by combustion turbine loading and duct burner exhaust temperature.

7-6.2 The firing rate shall be regulated by varying the fuel to individual burners by means of a fuel control valve(s) or by staged firing where burners are brought in or taken out of service. Individual burner safety shutoff valves shall not be used to vary the fuel rate of the burner elements. All safety shutoff valves shall be fully open or completely closed; intermediate settings shall not be used.

7-6.3 The burner fuel shall be maintained within a range that falls between the maximum and minimum limits specified by the burner and HRSG manufacturers, or as determined by trial. These trials shall test for minimum load and for stable flame as follows:

(a) With all burners in service and combustion control on automatic; and

(b) With different combinations of burners in service and combustion control on automatic.

Where changes occur to the minimum and maximum limits because of various burner combinations and fuel conditions, retesting shall be required.

7-6.4 On loss of an individual burner flame, that burner's individual safety shutoff valve and the associated igniter safety shutoff valve shall close.

7-7 Normal Shutdown.

7-7.1 Burners shall be shut down sequentially as load is reduced by closing the individual burner safety shutoff valves.

7-7.2 The duct burners shall be taken out of service with verification that the safety shutoff valves are secured in the closed position.

7-7.3 When taking the unit (combustion turbine and duct burner) out of service, the combustion turbine load shall be reduced in accordance with the manufacturer's shutdown procedures.

7-7.4 Steam flow shall be maintained through the superheater as necessary.

7-7.5 The normal coast-down of the combustion turbine shall be considered to provide a post purge of the unit.

7-7.6 After completion of the post purge in 7-7.5, consideration shall be given to maintaining airflow through the unit to prevent accumulation of combustible gases.

7-7.7 Leakage of fuel into the unit shall be prevented.

7-8 Normal Hot Restart.

7-8.1 When restarting a hot combustion turbine, the requirements for cold start preparation as described in 7-3(d) through (j) shall be followed.

7-8.2 The starting sequences of Sections 7-4 and 7-5, if required, shall be followed.

7-9 Duct Burner Emergency Shutdown.

7-9.1 A duct burner master fuel trip shall be initiated by the conditions identified in Chapter 6.

7-9.2 Gas. A duct burner master fuel trip shall stop all fuel flow to the HRSG from all burners by tripping the main and individual burner safety shutoff valves. All vent valves shall be opened. The igniter safety shutoff valve and individual igniter safety shutoff valves shall be tripped and igniter sparks deenergized. Master fuel trips shall operate to stop all fuel flow to the burners within a period of time that does not allow a dangerous accumulation of fuel in the HRSG. All igniters or other ignition sources shall be tripped.

7-9.3 Oil. A duct burner master fuel trip shall stop all fuel flow to the HRSG from all burners by tripping the main and individual burner safety shutoff valves. The igniter safety shutoff valve and individual igniter safety shutoff valves shall be tripped and igniter sparks deenergized. Master fuel trips shall operate to stop all fuel flow to the burners within a period of time that does not allow a dangerous accumulation of fuel in the HRSG. All igniters or other ignition sources shall be tripped.

7-9.4 The burners shall not be reignited until the initiating trip condition has been investigated and corrected and a unit purge has been completed.

Chapter 8 Inspection, Maintenance, Training, and Safety

8-1 Equipment Inspection and Maintenance. The owner or the owner's representative shall be responsible for ensuring that there is a comprehensive inspection and maintenance program for the equipment. The program shall provide for the maintenance of equipment at intervals consistent with the type of equipment, its service requirements, industry practice, and the manufacturers' recommendations.

8-1.2 Documentation of the plant equipment, the system, and maintenance activities shall be updated to reflect changes in the status of equipment and operating procedures accurately.

8-1.3 As a minimum, the maintenance program shall include the following:

(a) In-service inspections to identify conditions requiring corrective action or further study;

(b) Detailed, knowledgeable planning for effecting repairs or modifications using qualified personnel, established procedures, and appropriate equipment;

(c) Use of detailed equipment history that records conditions found, maintenance work done, changes made, and date of each;

(d) Written, comprehensive maintenance procedures incorporating manufacturers' instructions that specify tasks and skills required; specification of any special techniques, such as nondestructive testing or tasks needing special tools; special environmental factors, such as temperature limitations, dust, contaminated or oxygen-deficient atmosphere, internal pressures, and limited access or confined space requirements;

(e) Shutdown maintenance inspections that are thorough in scope, to cover all areas that have been identified during operation as needing attention, in addition to the routine checklist items; and

(f) Maintenance of adequate spare parts meeting specifications that provide reliable service without necessitating makeshift repairs.

8-1.4 An inspection and maintenance schedule shall be established and followed.

8-1.5 Inspections, adjustments, and repairs shall be performed by trained and qualified personnel, using tools and instruments suitable for the work. Maintenance and repairs shall be accomplished in accordance with the manufacturers' recommendations and applicable standards, codes, and safety regulations.

8-1.6 Operation set point and adjustments shall be verified periodically, and the results shall be documented.

8-1.7 Defects shall be reported and corrected, and the repairs shall be fully documented.

8-1.8 Inspection or maintenance personnel shall not make any changes to the system configuration, including logic, set points, and sensing hardware, without evaluation of the effects on operation and safety and the advance authorization of changes. All changes shall be documented.

8-1.9 In pressurized (positive pressure) installations, inspection or maintenance personnel shall check for and report any combustion-gas leakage through casings, ductwork, expansion joints, or dampers.

8-1.10 Where a unit that fires liquid fuel is out of service and available for inspection, personnel shall check for any accumulation of unburned fuel in the HRSG enclosure, especially in the fin-tube area.

8-1.11 During planned maintenance outages, stack dampers shall be inspected for proper operation and position indication.

8-2 Training.

8-2.1 Operator Training.

8-2.1.1 The owner or the owner's representative shall be responsible for establishing a formal and ongoing program for training operating personnel. The training program shall prepare personnel to operate the equipment safely and effectively. This program shall consist of study or review of operating manuals, videotapes, and programmed instruction and examinations, computer simulation (if available), and supervised hands-on field training. The training program shall apply specifically to the type of equipment and the hazards involved.

8-2.1.2 Before operators shall be permitted to assume their responsibilities, the owner or the owner's representative shall certify that they are trained and competent to operate the equipment under all possible conditions.

8-2.1.3 The owner or the owner's representative shall be responsible for periodic retraining of operators, including review of their compentency.

8-2.1.4 The training program and manuals shall be reviewed periodically to keep them current with changes in equipment and operating procedures. The training program and manuals covering operation and maintenance procedures shall be readily available for reference and use at all times.

8-2.1.5 Operating procedures that cover both normal and emergency conditions shall be established. Start-up and shutdown procedures, normal operating conditions, and lockout procedures shall be covered in detail in operating manuals and in the associated training programs.

8-2.1.6 Operating procedures shall be directly applicable to the equipment involved and shall be consistent with safety requirements and the manufacturer's recommendations.

8-2.1.7 Operators shall be trained in the proper procedures for reducing load or tripping the system whenever there is a potential for an unsafe condition that could lead to danger to personnel or property damage. The operator shall be authorized to take appropriate action, including reducing load, tripping equipment, or calling for outside assistance in case of emergency.

8-2.2 Maintenance Training.

8-2.2.1 The owner or the owner's representative shall be responsible for establishing a formal and ongoing program for training maintenance personnel. The training program shall prepare personnel to perform any required maintenance tasks safely and effectively. This program shall consist of study or review of maintenance manuals, videotapes, and programmed instruction and examinations, field training, and training by equipment manufacturers, among others. The training program shall apply specifically to the type of equipment and the hazards involved.

8-2.2.2 Maintenance procedures and their associated training programs shall be established to cover routine and special techniques. Any possible environmental factors such as temperature, dust, contaminated or oxygen-deficient atmosphere, internal pressures, and limited access or confined space requirements shall be included.

8-2.2.3 Maintenance procedures shall be consistent with safety requirements and manufacturers' recommendations.

The procedures contained in the training programs shall be reviewed periodically to keep them current with changes in equipment and personnel. They shall be used in the indoctrination and training of new maintenance personnel.

8-2.2.4 Maintenance personnel shall be trained to notify operating personnel in writing of any changes made in safety and control devices.

8-2.2.5 Maintenance personnel shall be trained to be knowledgeable of and to adhere to all Occupational Safety and Health Act (OSHA) safety procedures.

Chapter 9 Gas Bypass and Alternate Burner Systems

NOTE: This chapter is reserved for future use. It is anticipated that the information contained in Appendix C will provide the basis for this chapter.

Chapter 10 Fully Fired Systems

(Reserved)

Chapter 11 Referenced Publications

11-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

11-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers*, 1995 edition.

11-1.2 Other Publications.

11-1.2.1 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME B31.1, *Power Piping*, 1992.

11-1.2.2 ASTM Publications. American Society of Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM D396, *Standard Specification for Fuel Oils*, 1992.

ASTM D1655, *Standard Specification for Aviation Turbine Fuels*, 1994.

ASTM D2880, *Standard Specification for Gas Turbine Fuel Oils*, 1994.

11-1.2.3 U.S. Department of Defense Publication. Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

MIL-T-5624, *Turbine Fuel, Aviation, Grade JP4, JP5, and JP5/JP8 ST*, 1995.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-4-3.1 The following provides a list of factors that, at minimum, should be considered during the design evaluation:

(a) Single vs multiple steam pressure levels;

(b) Allowable combustion turbine exhaust backpressure;

(c) Supplementary, auxiliary, or augmented firing;

(d) Combustion turbine exhaust bypass system;

(e) Corrosiveness and fouling of by-products of combustion (fin tube vs bare tube, metallurgy, cold-end metal temperature);

(f) Single or multiple fuels;

(g) SCR or other environmental control systems;

(h) Heat transfer surface cleaning (during operation and shutdowns) and inspection;

(i) Freeze protection;

(j) Rapid start, operating transients, thermal shock;

(k) Dry operation;

(l) Protective systems;

(m) Degree of automation and complexity of control systems;

(n) Operator interface;

(o) Overall system performance evaluation, feedback, and iteration (expert system database consideration);

(p) Description of start-up validation test program (reference test cases and simulator data library where available);

(q) Combustion turbine (purge exhaust);

(r) Bypass stack, damper;

(s) HRSG and interconnecting ducts;

(t) Forced draft fan, induced draft fan, or discharge stack, in any combination;

(u) Burner management system logic;

(v) Flame monitoring and tripping systems;

(w) Combustion control system;

(x) Power supplies configuration and codes;

(y) Piping system configuration and codes;

(z) Operating information;

(aa) Input/output selection;

(bb) Information displayed;

(cc) Data transmission (noise accuracy considerations);

(dd) Programmable logic controller software and hardware considerations;

(ee) Requirements for operation from a remote location; and

(ff) Initial control tuning.

A-4-3.2 Dynamic simulation, where utilized, should include development of the following:

(a) Configuration and data initialization;

(b) Plant behavior knowledge development;

(c) Preliminary control system design and tuning;

(d) Validation of operating requirements (system performance); and

(e) Transients and ramps for intended and unintended operation.

A-5-3 General. The operation of the HRSG combustion turbine system differs from a conventional multiple burner boiler. Some of the differences include:

(a) The combustion turbine is an internal combustion engine. The engine burns a lean mixture of fuel with compressed air. The hot, pressurized combustion gases expand from the combustion chamber, through a series of rotating turbine wheel and blade assemblies, resulting in shaft power output and hot turbine exhaust gas discharge to the HRSG. Turbine exhaust gas is hot and has a reduced oxygen content relative to air.

(b) The design of the HRSG differs from that of a regular steam generator in that, in most cases, the HRSG is designed to utilize the residual heat from the combustion turbine exhaust gas, with some supplementary firing by the duct burner, if necessary.

(c) Because the combustion turbine is a volumetric machine, combustion turbine exhaust gas is discharged within closely prescribed limits, with the oxygen content varying as a function of load.

(d) Separate purge requirements exist prior to combustion turbine light-off and prior to duct burner light-off.

(e) Air/fuel ratios controlled by duct burners are neither possible nor recommended. As vast quantities of turbine exhaust gas that are far in excess of the stoichiometric requirements of the fuel are utilized, fuel-rich conditions cannot inherently occur under normal controlled operating conditions.

(f) Many types of burners are available for HRSG systems. The burner can consist of a number of parallel tubes or runners placed in the duct to provide the required heat release. This commonly is used for gaseous fuels and is referred to as a "grid" burner. Alternatively, wall-mounted burner systems with parallel flame holders within the duct can be used for liquid fuels. In-line register-type burners manufactured in Europe also have been used. Ignition systems for these burner types can employ Class 1, Class 2, or Class 3 igniters.

A-5-3.2.2.2 Atmospheric vent valves located between shutoff valves are intended to relieve any gas pressure that builds up due to failure of the first (upstream) shutoff valve. This minimizes the potential for leakage into an idle HRSG. To perform properly, these valves should be large enough to relieve gas to the atmosphere at a rate equal to the potential leakage rate. In the absence of equivalent protection, vent pipe sizes and vent valve port diameters should conform to Table A-5-3.2.2.2. Where vents are manifolded from safety shutoff systems, the cross-sectional area of the manifold pipe should be equal to, or greater than, the sum of the cross-sectional areas of the two largest vents involved.

A-5-3.2.3.8 A permanent and ready means for making easy, accurate, periodic tightness tests of the main safety shutoff valves and individual burner safety shutoff valves generally is not feasible for fuel oil systems. However, a visual check of the burners and combustion area prior to starting operation can determine if leakage has occurred. Also, pressurizing the oil supply header with the individual burner safety shutoff valves and the recirculating valves closed indicates if leakage is present. If oil pressure remains within defined limits, it can be concluded that the individual burner safety shutoff valves are not leaking.

Table A-5-3.2.2.2 Vent Line Sizes

Gas Supply Line Size (in.)	(mm)	Shutoff System Vent Port Size (in.)	(mm)
≤ 1½	≤ 38	¾	19
2	50.8	1	25.4
2½ to 3	64 to 76	1¼	31.8
3½	89	1½	38
4 to 5	102 to 127	2	50.8
5½ to 6	139.7 to 152.4	2½	64
8	203	3½	89
> 8	> 203	15% of supply line cross-sectional area	

A-5-4 Proper design consideration should be given to internal insulation and cover plates so that the following factors are properly addressed:

(a) Insulation thickness and external casing temperature calculations;

(b) Internal plate thickness and material;

(c) Pin pitch, diameter, and fixing methods; and

(d) Welding procedures.

A-5-4.1 The external skin temperature and acoustical design of the HRSG, HRSG ducts, and HRSG stack should comply with the requirements of federal, state, and local regulations.

A-5-4.3 Any through-duct penetrations should have proper provision for expansion and sealing. Where pipes, tubes, headers, or drums create a through-duct penetration, calculations should be provided to demonstrate that the differential expansion and the sealing can properly accommodate such expansion.

A-5-4.4 Access should be provided for proper maintenance and repair. This should include personnel access where allowed by ducting. All pressure parts should have access for periodic inspection and for mandatory hydraulic tests.

A-5-4.8.1 Consideration should be given in the design to minimizing pockets that could trap combustible materials.

A-5-4.8.2 Drains should be provided in all ducts or enclosures where fluid accumulation is possible.

A-5-5 Some HRSG systems are required by some authorities to install selective catalytic reduction systems to reduce the emissions of NO_x. Because such a system has a narrow range of optimum operating temperatures and is subject to maximum temperature limitations lower than many combustion turbine full-load exhaust temperatures, it usually is installed between heat transfer surfaces within the HRSG.

The chemical process of reduction necessitates the addition of ammonia to reduce NO_x to nitrogen and water in the presence of the catalyst. In addition, if the fuel contains sulfur, a reaction that results in the formation of ammonium bisulfate can occur. This material tends to deposit on both the catalyst and metallic surfaces downstream of the reactor section, primarily at low temperatures. Although troublesome in terms of corrosion, fouling, and material life, ammonium bisulfate does not directly affect flame safety.

It is common practice to use either anhydrous or aqueous ammonia as the reducing agent in a selective catalytic reduction (SCR) system. These chemicals are not interchangeable, and a specific system design is needed, depending on the form to be used at a particular installation. Both forms, on release, are considered a potential health hazard. Ammonia gas is flammable in air at concentrations between 16 percent to 25 percent by volume. Such concentrations usually are not encountered. The system should provide the necessary features to ensure such concentrations cannot occur during abnormal conditions.

Aqueous ammonia usually is stored in a closed vessel to prevent the release of vapor. Such vessels are designed for low [less than a gauge pressure of 50 psi (344.7 kPa)] pressures and only approach the design pressure under high ambient temperature conditions. Due to the corrosive nature of ammonia, material selection is an important consideration.

Anhydrous ammonia is stored in a concentrated liquid/vapor form within closed vessels. Under ambient temperature conditions, higher pressures than those observed with aqueous ammonia can result. Vessels built in accordance with the ASME *Boiler and Pressure Vessel Code* are required with design gauge pressures of 250 psi (1723.7 kPa) or higher. The following sources provide additional information and requirements for storage and handling of anhydrous ammonia: CGA G-2, *Anhydrous Ammonia; Code of Federal Regulations*, Title 29, Part 1910.111, "Storage and Handling of Anhydrous Ammonia"; and ANSI K61.1, *Safety Requirements for the Storage and Handling of Anhydrous Ammonia*.

A-6 Guidelines for the Application of Distributed Control Systems.

NOTE: The user of NFPA 8506 is encouraged to use judgment in the application of these guidelines for all process and safety functions contained in the distributed control system. This section is not intended to apply specifically to burner management systems.

(a) *Data Transmission.*

1. Every input should be sampled at an interval no longer than 1 second. Every output should be updated at an interval no longer than 1 second.

2. For protective actions, the system should be able to convert a changed input sensor value to a completed output control action in less than 250 milliseconds.

3. Changes in displayed data or status should be displayed within 5 seconds.

4. Data acquisition and transmission systems should be protected from noise pickup and electrical interference.

5. In redundant systems, the data links should be protected from common mode failures. Where practical, redundant data links should be routed on separate paths to protect against physical damage that disables both data links.

(b) *Hardware.*

1. The hardware selected should have adequate processor capacity to perform all the functions required for start-up sequencing, normal operation alarming, monitoring, and shutdown of the controlled equipment. Capacity also should be available for data storage and sorting; this may be permitted to be located in a separate processor.

2. Selection should take into consideration the requirements for reliability, maintainability, and electrical classification.

3. The hardware should provide for automatic tracking between auto/manual functions to allow for immediate seamless transfer.

4. The hardware should be capable of stable dynamic control.

5. The hardware should be capable of thorough self-diagnosis.

6. Consideration should be given to all levels and types of electrical interference that can be tolerated by the hardware without compromising its reliability or effectiveness.

7. Fail-safe operation should be obtained through a thorough and complete analysis of each control loop and by providing for a failure of that loop (i.e., valve/actuator) to cause a fail-safe position.

(c) *Software.*

1. The software package should be designed to include all logic to provide a safe and reliable control system. When the software calls for the operation of a field safety device, a feedback signal should be provided to prove that the requested operation has taken place, and an alarm should be actuated if the action is not confirmed in a specified time.

2. The software package should be checked to ensure that no unintended codes or commands are present (e.g., viruses or test breaks). The software package should be tested and exercised before being loaded into the plant site computers or processors.

3. The software system should be protected from inadvertent actions from operators and also should be tamperproof.

4. Written procedures should specify the functions that can and cannot be accessed by the operator and those functions that require additional authorization for access.

5. The software may be permitted to provide for authorized on-line changes of the timers and set points, provided the safety of the operating equipment is not compromised.

6. The software should implement and enhance the self-diagnostic hardware that has been provided.

A-6-6.4 A sequence of events recorder, where provided, should time-tag events with a resolution of 10 milliseconds or less.

A-7-1.1 Special Problems. Common hazards are involved in the combustion of liquid and gaseous fuels. In addition, each of these fuels has special hazards related to its physical characteristics.

(a) *Gas Firing.* The following items should be considered in the design of the fuel gas firing systems:

1. Gas is colorless; therefore, a leak usually cannot be detected visually. Also, reliance cannot be placed on detection of a gas leak by means of the presence of odor.

2. Potentially hazardous conditions are most likely to occur within buildings, particularly where the gas piping is routed through confined areas. In the latter instance, adequate ventilation should be provided. Outdoor steam generators tend to minimize confined area problems.

3. Natural gas can be either "wet" or "dry." A wet gas usually implies the presence of distillate, which could be characteristic of a particular source. In the case of such a wet gas, the carryover of distillate into the burners could result in a momentary flameout and possible reignition.

Reignition could result in an explosion. Therefore, special precautions should be taken with wet gas supply systems. (*See NFPA 54, National Fuel Gas Code.*)

4. Discharges from relief valves or from any other form of atmospheric vents can become hazardous unless special precautions are taken.

5. Maintenance and repair of gas piping can be hazardous unless proper methods are used for purging and recharging the line before and after making the repairs. (*See NFPA 54, National Fuel Gas Code.*)

(b) *Oil Firing.* The following items should be considered in the design of the fuel oil firing systems:

1. Firing of oil fuel into an HRSG can create a special hazard by causing soot accumulations in low-temperature sections.

2. Small oil leaks can result in serious fire damage.

3. Water or sludge in fuel oil storage tanks or improperly located suction takeoffs from the storage tank can result in hazardous interruptions or pulsations of the fuel supply to the burners. A flameout, either immediately or at a later time, can result because of plugged strainers or burner tips.

4. Widely different characteristics of fuel oil from either a single source or multiple sources can result in a significant change in Btu input rate to the burner(s). Different shipments of fuel oil with dissimilar characteristics can cause a precipitation of sludge that can lead to hazards as described in A-7-1.1(b)3.

5. Inserting an oil gun in the burner assembly without a tip, new gaskets, or a sprayer plate is a constant hazard. This can result in an unsafe operating condition.

6. Clear distillate fuels have low rates of conductivity and generate static electrical charges in the fuel stream that can be dangerous unless flowing velocities are limited. (*See NFPA 77, Recommended Practice on Static Electricity, and API RP 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents.*)

7. Maintenance and repair of oil piping can be hazardous unless proper methods are used for purging and recharging the line before and after making repairs. (*See NFPA 31, Standard for the Installation of Oil-Burning Equipment.*)

8. The incompressibility of fuel oil can create very rapid transients in oil flow through operating burners when the following occur:

a. Rapid operation of oil the supply valve;

b. Rapid operation of individual burner shutoff valves; and

c. Rapid operation of the regulating valve in the return oil line from the burner header (on systems using this type of control).

(c) *Fuel Oil—General Considerations.*

1. The term fuel oil refers to liquid fuels with widely differing characteristics. A fuel oil burning system is designed for a specific range of oil characteristics. Attempting to burn an oil whose characteristics differ widely from those for which the system is designed can cause serious operating difficulties and potential safety hazards. Therefore, care should be exercised to ensure that fuel oil received at a plant is within the specified range of the handling and burning equipment.

2. The more important characteristics of fuel oils are provided in ASTM specifications. It is relatively simple to identify oils that require special provisions for storing and functions such as heating, pumping, and atomizing. Generally speaking, grades 2 and 4 have lower viscosities and less water and sediment than grades 5 or 6 and so require fewer special provisions to ensure proper handling and burning. However, most boiler fuel oil systems are designed for grades 5 and 6, which are heavier; therefore, such systems include provisions for preheating these usually viscous fuels. Furthermore, more care is necessary in the design and operation of fuel oil systems supplied with grade 6 oil than with the other ASTM grades. Care should be taken to avoid flameouts attributable to interruptions or pulsation of the fuel supply or plugging of strainers or burner tips.

3. All of the following characteristics can have an affect on the proper and safe burning of fuel oils:

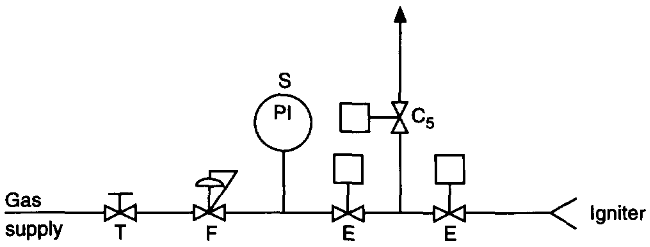
a. Fuel oil is a complex mixture of hydrocarbons of differing molecular weights and boiling and freezing points. When subjected to sufficiently high temperature, accumulations of the fuel partially decompose and volatilize, thus creating new liquid, gaseous, and solid fuels with unpredictable properties.

b. Fuel oil should be introduced into the furnace as an extremely fine mist in order to mix intimately with the combustion air so that it can burn quickly and completely. In boilers, this is accomplished by spraying the fuel oil through small orifices with high pressure drops (mechanical atomization) or by using steam or air to break up small oil streams. Viscosity and volatility are characteristics of the oil that indicate ease of atomization.

c. Viscosity affects ease of pumping and atomization. Temperature significantly affects viscosity.

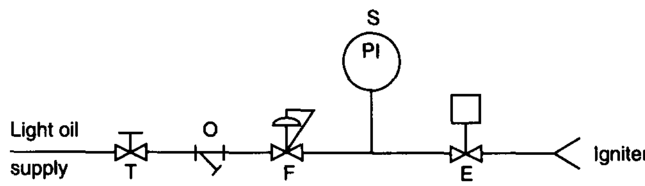
d. Flash point is an indicator of the volatility and, thus, of potential for combustible vapors.

e. Some fuel oils contain constituents that, when overheated, can decompose and form solids or can solidify when exposed to low ambient temperatures. The presence of such solids in the fuel can cause interruptions.



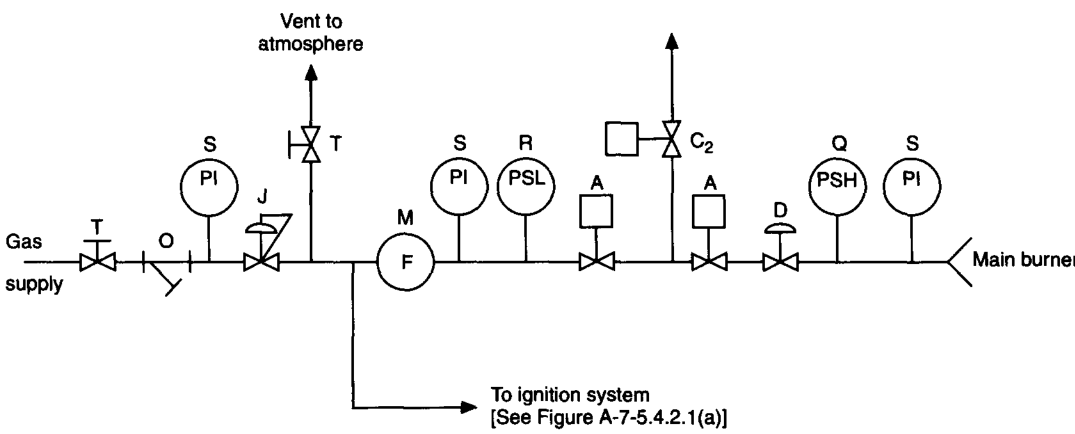
C_5 Igniter shutoff atmospheric vent valve
E Igniter safety shutoff valve
F Igniter fuel control valve
S Fuel pressure gauge
T Manual shutoff valve

Figure A-7-5.4.2.1(a) Typical duct burner gas ignition system of a single element or multiple elements fired simultaneously (Class 3 igniter monitoring requirements shown).



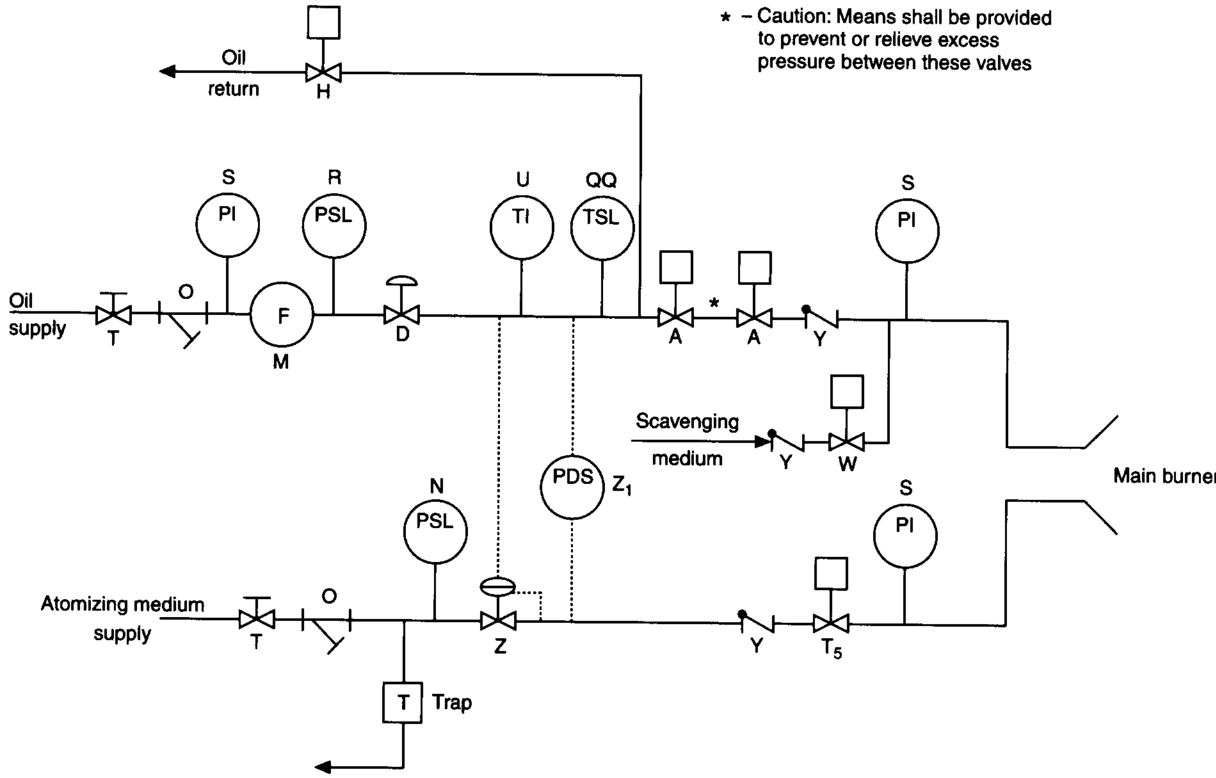
E Igniter safety shutoff valve
F Igniter fuel control valve (optional)
O Cleaner or strainer
S Fuel pressure gauge
T Manual shutoff valve

Figure A-7-5.4.2.1(b) Typical duct burner oil ignition system of a single burner or multiple burners fired simultaneously (Class 3 igniter monitoring requirements shown).



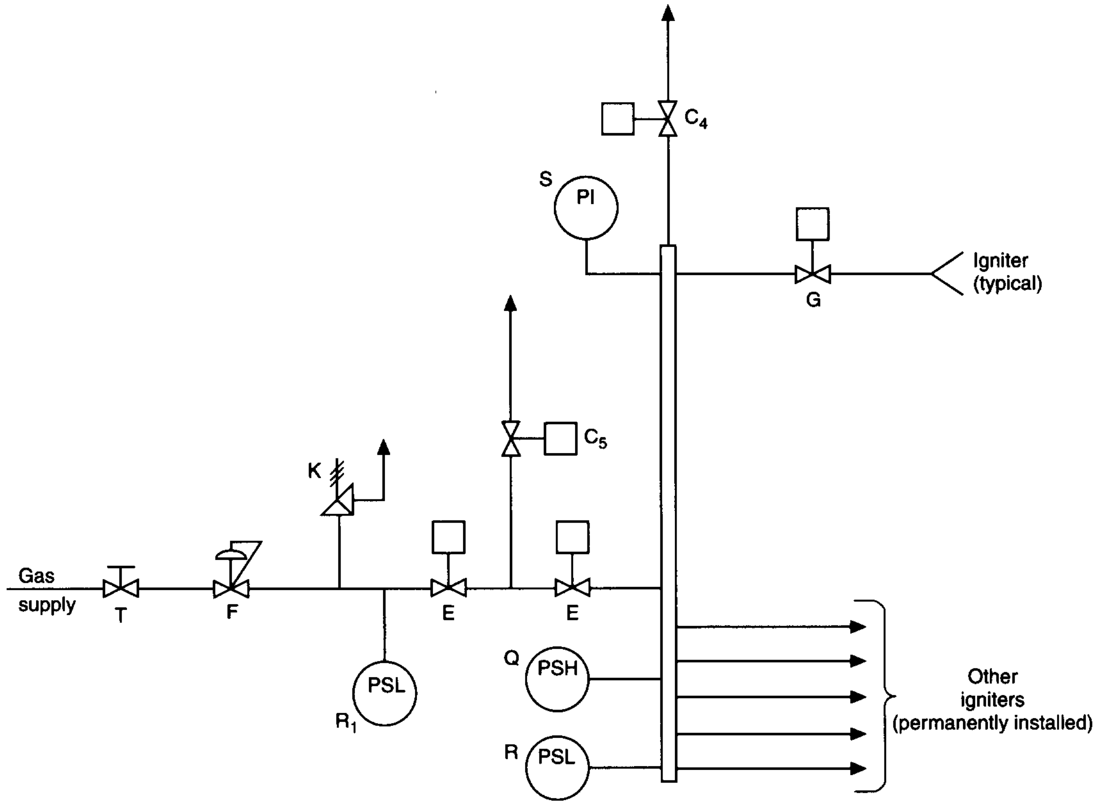
A Main burner safety shutoff valve
C_2 Main burner shutoff atmospheric vent valve
D Main fuel control valve
J Fuel pressure regulator (optional)
M Flow meter
O Cleaner or strainer
Q High fuel pressure interlock
R Low fuel pressure interlock
S Fuel pressure gauge
T Manual shutoff valve

Figure A-7-5.4.2.1(c) Typical main gas duct burner system of a single element or multiple elements fired simultaneously.



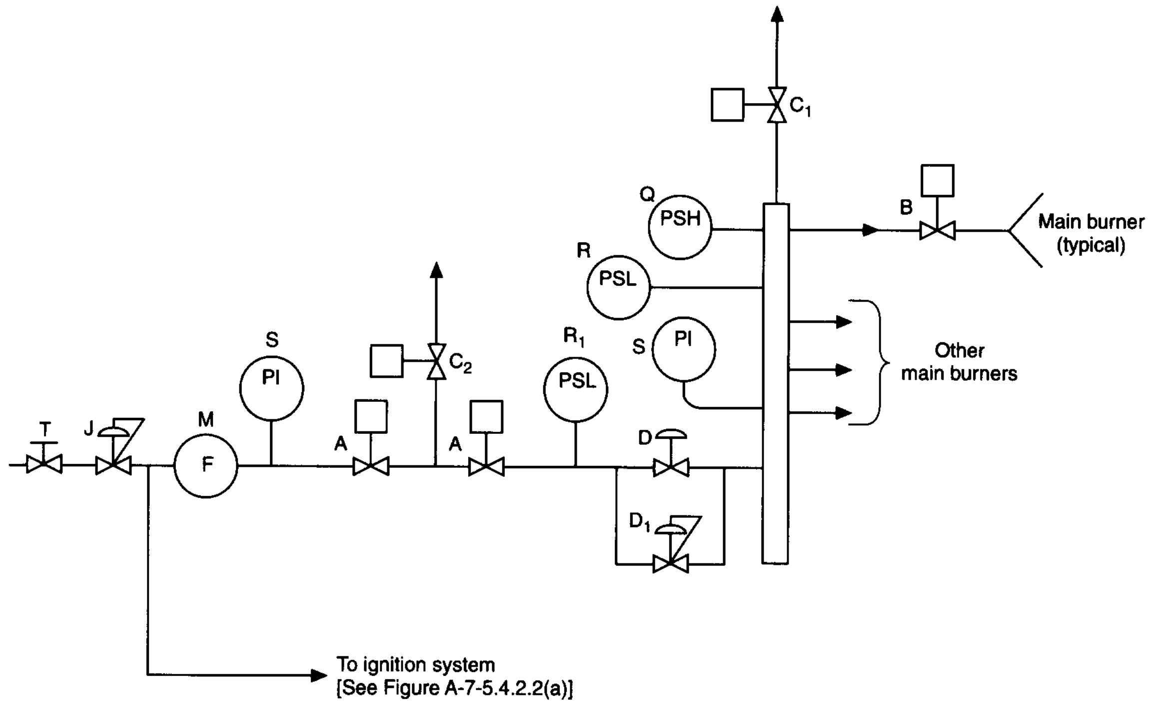
A	Main burner safety shutoff valve	S	Fuel pressure gauge
D	Main fuel control valve	T	Manual shutoff valve
H	Recirculating valve (optional for unheated oil)	T_5	Atomizing medium individual burner shutoff valve, automatic
M	Flow meter	U	Temperature gauge (optional for unheated oil)
N	Low atomizing pressure interlock	W	Scavenging valve
O	Cleaner or strainer	Y	Check valve
QQ	Low temperature or high viscosity alarm (optional for unheated oil)	Z	Differential pressure control valve
R	Low fuel pressure interlock	Z_1	Differential pressure alarm and trip interlock

Figure A-7-5.4.2.1(d) Typical steam or air atomizing single main oil duct burner system.



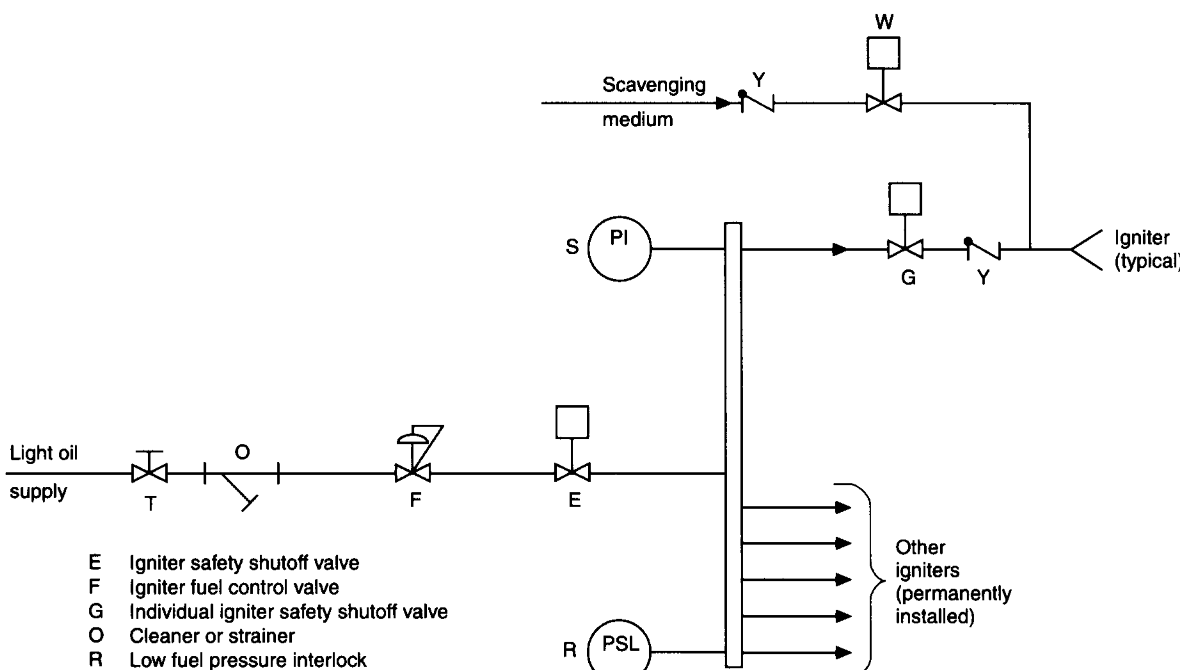
C_4 Igniter header atmospheric vent valve (optional)
C_5 Igniter supply atmospheric vent valve
E Igniter header safety shutoff valve
F Igniter fuel control valve
G Individual igniter safety shutoff valve
K Pressure relief valve
Q Low fuel pressure interlock
R High fuel pressure interlock
R_1 Low fuel pressure interlock (alternate location)
S Fuel pressure gauge
T Manual shutoff valve

Figure A-7-5.4.2.2(a) Typical duct burner gas igniter system.



A Main safety shutoff valve
B Individual burner safety shutoff valve
C_1 Main burner header charging atmospheric vent valve (optional)
C_2 Main burner header shutoff atmospheric vent valve
D Main fuel control valve
D_1 Main fuel bypass control valve (optional)
J Fuel pressure regulator (optional)
M Flow meter
Q Burner header high fuel pressure interlock
R Burner header low fuel pressure interlock
R_1 Burner header low fuel pressure interlock (alternate location for R)
S Fuel pressure gauge
T Manual shutoof valve

Figure A-7-5.4.2.2(b) Typical main gas duct burner system.



E Igniter safety shutoff valve
F Igniter fuel control valve
G Individual igniter safety shutoff valve
O Cleaner or strainer
R Low fuel pressure interlock
S Fuel pressure gauge
T Manual shutoff valve
W Scavenging valve
Y Check valve

Figure A-7-5.4.2.2(c) Typical duct burner mechanical atomizing light oil igniter system.

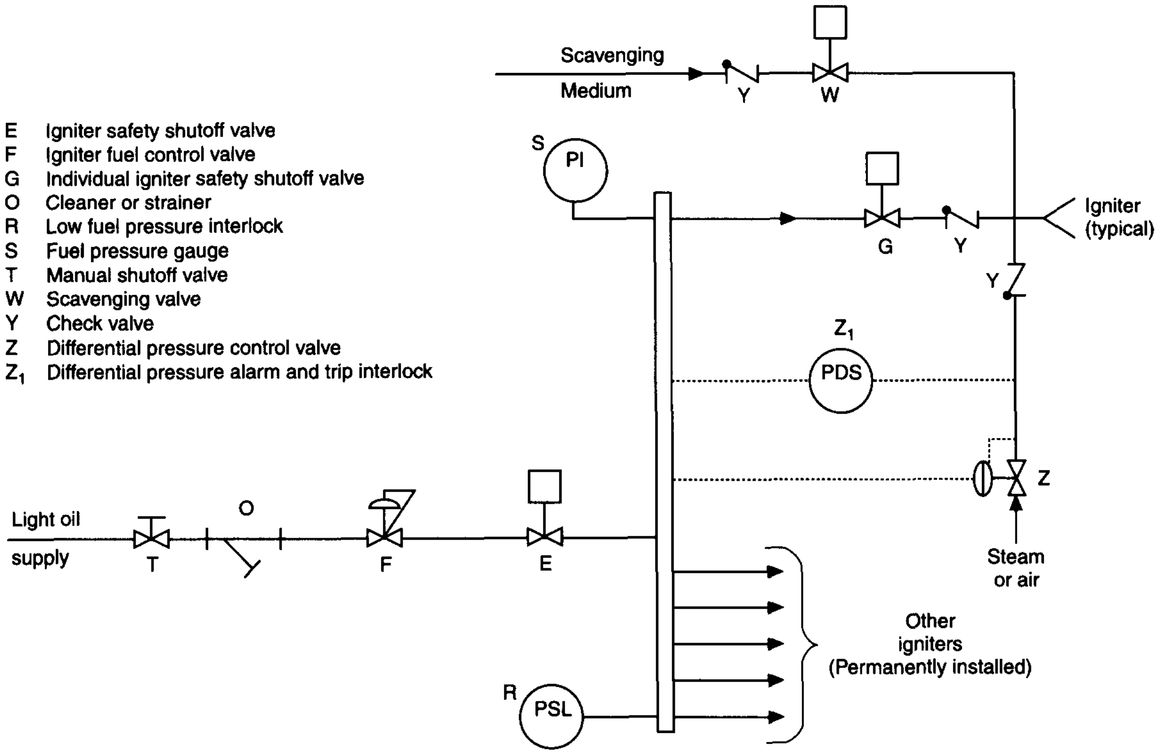
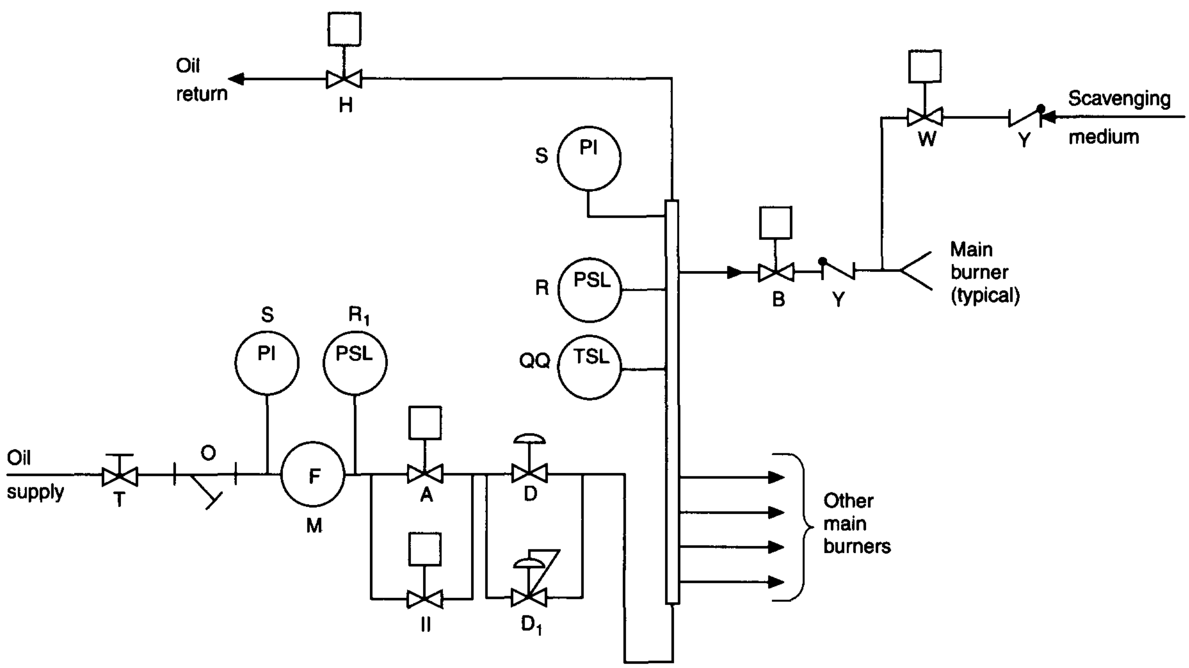
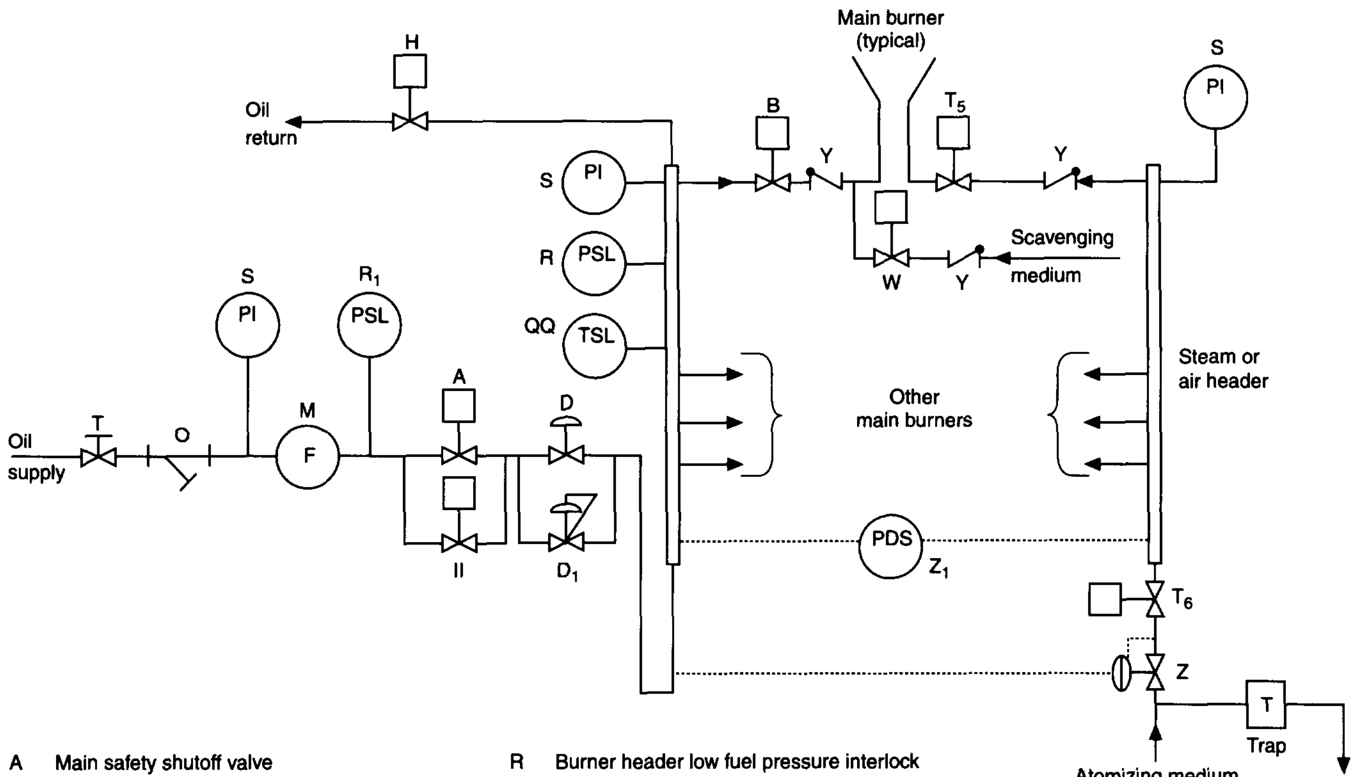


Figure A-7-5.4.2.2(d) Typical duct burner steam or air atomizing light oil igniter system.



A Main safety shutoff valve
B Individual burner safety shutoff valve
D Main fuel control valve
D_1 Main fuel bypass control valve (optional)
H Recirculating valve (optional for unheated oil)
II Circulating valve (optional for unheated oil)
M Flow meter
O Cleaner or strainer
QQ Low temperature or high viscosity alarm (optional for unheated oil)
R Burner header low fuel pressure interlock
R_1 Low fuel pressure interlock
S Fuel pressure gauge
T Manual shutoff valve
W Scavenging valve
Y Check valve

Figure A-7-5.4.2.2(e) Typical mechanical atomizing main oil duct burner system.



A Main safety shutoff valve
B Individual burner safety shutoff valve
D Main fuel control valve
D_1 Main fuel bypass control valve (optional)
H Recirculating valve (optional for unheated oil)
II Circulating valve (optional for unheated oil)
M Flow meter
O Cleaner or strainer
QQ Low temperature or high viscosity alarm (optional for unheated oil)
R Burner header low fuel pressure interlock
R_1 Low fuel pressure interlock
S Fuel pressure gauge
T Manual shutoff valve
T_5 Atomizing medium individual burner shutoff valve, automatic
T_6 Atomizing medium header shutoff valve, automatic (alternate to T_5)
W Scavenging valve
Y Check valve
Z Differential pressure control valve
Z_1 Differential pressure alarm and trip interlock

Figure A-7-5.4.2.2(f) Typical steam or air atomizing main oil duct burner system.

Appendix B Industry Experience

(Reserved)

Appendix C Gas Bypass and Alternate Burner Systems

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

C-1 General. The requirements in Chapters 1 through 8 apply to other combustion turbine and HRSG configurations (*see Figures C-2 through C-5*) except as amended or supplemented in subsequent sections of this chapter. There are additional safety considerations and requirements that apply where these configurations are used.

NOTE: Chapters 1 through 8 of this standard have been written based on a directly coupled combustion turbine and HRSG either with or without HRSG burners. Combustion turbine exhaust is the only source of heat to the HRSG where no HRSG burners are supplied and is the only source of combustion air for the HRSG burners where the HRSG system is so equipped. [*See Figures C-1(a) and (b).*]

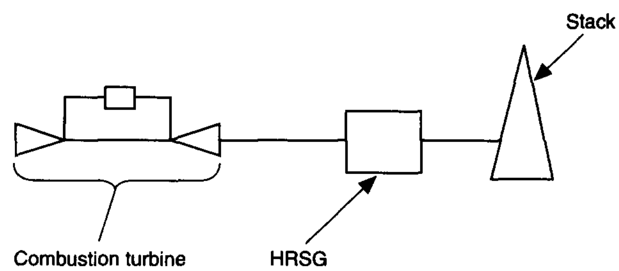


Figure C-1(a) Combustion turbine with directly coupled unfired HRSG.

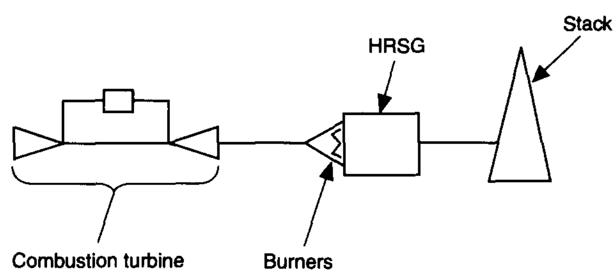


Figure C-1(b) Combustion turbine and directly coupled HRSG with burners.

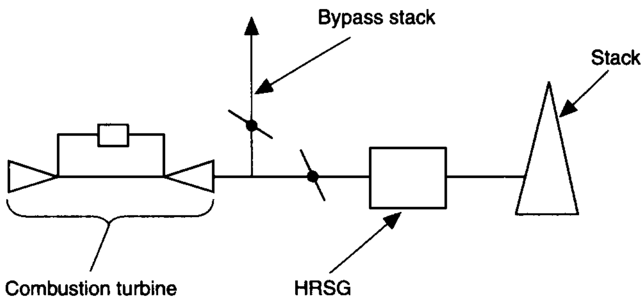


Figure C-2 Combustion turbine and unfired HRSG with bypass stack.

C-2 Combustion Turbine and Unfired HRSG with Bypass Stack. See Figure C-2.

NOTE: Figure C-2 shows separate devices for isolating gas flow to the HRSG and allowing gas flow to the bypass stack. The recommendations of Section C-2 apply regardless of physical hardware [i.e., single-blade directing damper, two separate dampers (single or multi-blade) for isolation or bypass service, or multiple dampers in series with seal air provision].

C-2.1 Gas Bypass Stack and Damper System.

C-2.1.1 The gas bypass stack and damper housing should be capable of withstanding a transient design pressure without permanent deformation due to yield or buckling of any support member. (*See 5-4.2.*)

C-2.1.2 Means should be provided for recognizing leakage of combustion turbine exhaust gas past the closed damper and into the HRSG by gas analysis or some other means. Alternatively, a sealing air fan and double damper system can be provided. If a double damper with seal air fan is utilized, the fan is to be run continuously with closed dampers from the time of previous purge described in C-2.5 until hot exhaust gas is admitted into the HRSG.

C-2.1.3 Convenient access to the inside of the ducts should be provided.

C-2.1.4 The damper system for the gas bypass stack normally should be either fully open to the HRSG or fully open to the bypass stack. Intermediate damper positions normally should be used only during the HRSG start-up or shutdown periods. If the application needs indefinite periods of intermediate position operation, the combustion turbine exhaust or airflow should be monitored for quantity and direction with appropriate alarms for conditions abnormal to the design.

C-2.1.5 During planned maintenance outages the following should be accomplished:

(a) The damper system should be inspected for tightness while the damper(s) is fully closed;

(b) The damper operating devices should be checked for proper operation and positioning; and

(c) Correct damper system positioning during purge, start-up, and shutdown should be verified by functional test.

C-2.2 Monitoring.

C-2.2.1 In addition to the requirements of 6-2.3, combustion turbine exhaust or airflow through the HRSG should be monitored continuously if the bypass stack damper(s) can be maintained in an intermediate position.

C-2.2.2 In addition to the requirements of 6-2.3, the position of the bypass stack damper(s) should be monitored continuously.

C-2.3 In addition to the alarms required in 6-3.2, reverse flow through an HRSG (airflow from exhaust stack through HRSG to bypass stack) should be alarmed if the bypass damper system can be maintained in an intermediate position. (*See C-2.1.4.*)

C-2.4 Interlocks.

C-2.4.1 As a supplement to the combustion turbine starting permissive interlock in 5-2.3.1(e) [position of the stack closure damper (if provided) correct], the damper allowing gas flow into the HRSG also should be proven open. As an alternative, the gas bypass stack damper(s) in the bypass position should be interlocked to allow combustion turbine start-up regardless of stack closure damper position.

C-2.4.2 As a supplement to the combustion turbine tripping interlock in 5-2.3.2(c) [position of stack closure (if provided) not correct], it may be permitted to position the gas bypass damper(s) in the bypass position as an alternative to tripping the combustion turbine.

C-2.5 Purge.

C-2.5.1 Following a combustion turbine shutdown, a unit purge should be completed as required in Section 7-4 prior to admitting combustion turbine exhaust gas into the HRSG.

C-2.5.2 Following the purge as recommended in C-2.5.1, flow through the HRSG may be interrupted using the gas bypass stack, provided there is no fuel source in the HRSG. Combustion turbine exhaust flow may re-enter the HRSG at a later time without repurging, provided the combustion turbine has been in continuous operation with no trips or misfires.

C-2.5.3 The combustion turbine may be permitted to purge and operate with combustion turbine exhaust through the bypass stack without purging the HRSG. However, combustion turbine exhaust gas should not be directed into the HRSG unless a purge as recommended in C-2.5.1 and C-2.5.2 has been performed.

C-2.5.4 As an alternative to the purge recommendations, prior to HRSG start as specified in C-2.5.3, a permanently installed combustible gas analyzer should be installed to verify the absence of combustible gases in appropriate locations within the HRSG enclosure prior to starting the HRSG from an operating combustion turbine in gas bypass configuration.

C-3 HRSG Burners with Augmented Combustion Air Supply. See Figure C-3.

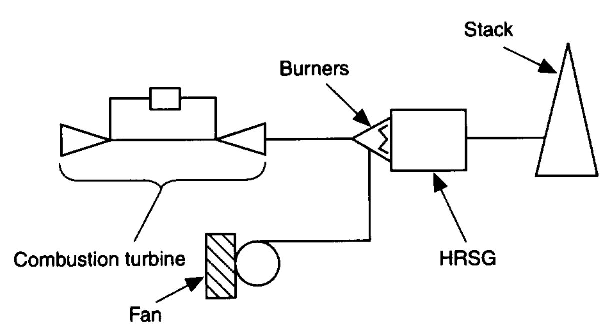


Figure C-3 HRSG burners with augmented combustion air supply.

C-3.1 The fan(s) supplying augmented combustion air to the HRSG burners should be operated in accordance with the manufacturer's instructions.

C-3.2 Interlocks.

C-3.2.1 The fan(s) supplying augmented combustion air to the HRSG burners should be proven to be operating prior to initiating and during a unit purge. (*See Section 7-4.*)

C-3.2.2 In addition to the master fuel trip requirements in 6-4.3, an HRSG burner master fuel trip should be initiated by loss of air from fans supplying augmented combustion air to the HRSG burners.

C-4 Combustion Turbine and Fired HRSG with Bypass Stack. See Figure C-4.

NOTE: Figure C-4 shows separate devices for isolating gas flow to the HRSG and allowing gas flow to the bypass stack. The recommendations of Section C-4 apply regardless of physical hardware [i.e., single-blade directing damper, two separate dampers (single or multi-blade) for isolation or bypass service, or multiple dampers in series with seal air provision].

C-4.1 Gas Bypass Stack and Damper System. The recommendations in C-2.1 should be satisfied.

C-4.2 In addition to the requirements of 6-2.3, combustion turbine exhaust or airflow through the HRSG should be monitored continuously.

C-4.3 In addition to the alarms required in 6-3.2, low flow and reverse flow through an HRSG (airflow from exhaust stack through HRSG to bypass stack) should be alarmed if the bypass damper system can be positioned in an intermediate position. (*See C-2.1.4.*)

C-4.4 Interlocks.

C-4.4.1 As a supplement to the combustion turbine starting permissive interlock in 5-2.3.1(e) [position of the stack closure damper (if provided) correct], the damper allowing gas flow into the HRSG also should be proven open. As an alternative, the gas bypass stack damper(s) in the bypass position should be interlocked to allow combustion turbine start-up regardless of stack closure damper position.

C-4.4.2 As a supplement to the combustion turbine tripping interlock in 5-2.3.2(c) [position of stack closure (if provided) not correct], it may be permitted to position the gas bypass damper(s) in the bypass position as an alternative to tripping the combustion turbine.

C-4.4.3 In addition to the required interlocks in 6-4.3, an HRSG burner master fuel trip should be initiated if the bypass stack damper is not closed or other means has determined that insufficient exhaust gas flow is entering the burner area.

NOTE: If the HRSG system is designed for maintaining the stack bypass damper(s) in an intermediate position, the interlock in C-4.4.3 is not necessary. However, the damper intermediate position should be interlocked or duct burner operation should be interlocked with turbine exhaust gas flow through the duct burners.

C-4.5 Purge.

C-4.5.1 Following a combustion turbine shutdown, a unit purge should be completed as required in Section 7-4 prior to admitting combustion turbine exhaust gas into the HRSG.

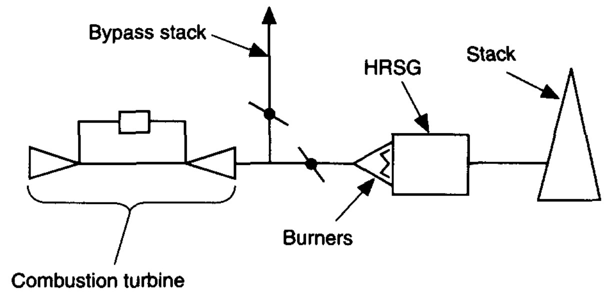


Figure C-4 Combustion turbine and fired HRSG with bypass stack.

C-4.5.2 Following the purge as recommended in C-4.5.1, interruption of the flow through the HRSG using the gas bypass stack should cause loss of purge of the HRSG. Combustion turbine exhaust flow should not be permitted to re-enter the HRSG at a later time without repurging the HRSG as specified in C-4.5.1.

C-4.5.3 The combustion turbine may be permitted to purge and operate with combustion turbine exhaust through the bypass stack without purging the HRSG. However, combustion turbine exhaust gas should not be directed into the HRSG unless a purge as recommended by C-4.5.1 and C-4.5.2 has been performed.

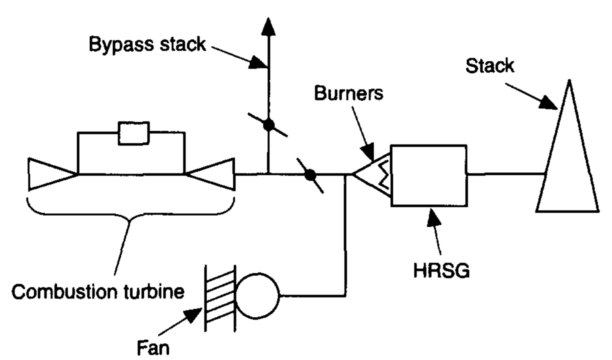
C-5 Combustion Turbine and HRSG with Fresh Air Firing Capability. See Figure C-5.

NOTE: Figure C-5 shows separate devices for isolating gas flow to the HRSG and allowing gas flow to the bypass stack. The recommendations of Section C-5 apply regardless of physical hardware [i.e., single-blade directing damper, two separate dampers (single or multi-blade) for isolation or bypass service, or multiple dampers in series with seal air provision].

C-5.1 Gas Bypass Stack and Damper System. The recommendations in C-2.1 should be satisfied.

C-5.2 In addition to the requirements in 6-2.3, combustion turbine exhaust or airflow through the HRSG should be monitored continuously.

C-5.3 In addition to the alarms required in 6-3.2, low flow and reverse flow through an HRSG (airflow from exhaust stack through HRSG to bypass stack) should be alarmed if the bypass damper system can be positioned in an intermediate position. (*See C-2.1.4.*)



Note: Fan could alternately be located between HRSG outlet and stack with combustion turbine exhaust or fresh air or both to burners and HRSG.

Figure C-5 Combustion turbine and HRSG with fresh air firing capability.

C-5.4 Interlocks.

C-5.4.1 As a supplement to the combustion turbine starting permissive interlock in 5-2.3.1(e) [position of the stack closure damper (if provided) correct], the damper allowing gas flow into the HRSG also should be proven open. As an alternative, the gas bypass stack damper(s) in the bypass position should be interlocked to allow combustion turbine start-up regardless of stack closure damper position.

C-5.4.2 As a supplement to the combustion turbine tripping interlock in 5-2.3.2(c) [position of stack closure (if provided) not correct], it may be permitted to position the gas bypass damper(s) in the bypass position as an alternative to tripping the combustion turbine.

C-5.4.3 A combustion turbine trip should cause a master fuel trip of the HRSG burners as required in 6-4.3 unless adequate flow through the HRSG burners can be maintained continuously by the fresh air supply.

C-5.5 Purge.

C-5.5.1 Following a combustion turbine shutdown, a combustion turbine purge should be completed as required in Section 7-4 prior to admitting combustion turbine exhaust gas into the HRSG. The fan for supplying combustion air for fresh air firing should be in operation prior to and during the this purge.

C-5.5.2 Following the purge as recommended in C-5.5.1, interrupting the flow through the HRSG using the gas bypass stack should cause loss of purge of the HRSG. Combustion turbine exhaust flow should not be permitted to re-enter the HRSG at a later time without repurging the HRSG as recommended in C-5.5.1. It may be permitted to perform this purge with fresh air supplied by the fan used for fresh air firing in accordance with C-5.6.2.

C-5.5.3 The combustion turbine may be permitted to purge and operate with combustion turbine exhaust through the bypass stack without purging the HRSG. However, combustion turbine exhaust gas should not be directed into the HRSG unless the recommendations of C-5.5.1, C-5.5.2, or C-5.6.3 have been satisfied.

C-5.5.4 Purge of the HRSG burners and HRSG using fresh air may be permitted without operation or purging of the combustion turbine, provided the gas bypass dampers are in the bypass position.

C-5.6 Sequence of Operations for Fresh Air Firing.

C-5.6.1 The sequence of operations defined in Section 7-3 should be followed.

NOTE: A fresh air supply should be used rather than combustion turbine exhaust.

C-5.6.2 A unit purge as required in Section 7-5 should be performed with an airflow of not less than 25 percent of the full-load fresh air mass flow. The unit purge should provide not less than five volume changes of the HRSG enclosure and should be of not less than 5 minutes duration.

C-5.6.3 A later start-up of the combustion turbine may be permitted only by purge and start-up of the combustion turbine with exhaust flow through the bypass stack. Once stable operation of the combustion turbine is achieved, combustion turbine exhaust may be permitted to flow through the operating HRSG with or without supplementary fresh air.

C-5.6.4 Normal shutdown using a fresh air supply should follow the reverse procedure of that used during start-up. A unit post purge should be performed at an airflow not less than the purge rate mass airflow for a period of not less than 5 minutes.

Appendix D Referenced Publications

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

D-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

D-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 70, *National Electrical Code*, 1996 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 497A, *Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1992 edition.

NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1991 edition.

NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, 1991 edition.

NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants*, 1992 edition.

D-1.2 Other Publications.

D-1.2.1 ANSI Publication. American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

ANSI K61.1, *Safety Requirements for the Storage and Handling of Anhydrous Ammonia*, 1981.

D-1.2.2 API Publications. American Petroleum Institute, 1220 L Street NW, Washington, DC 20005.

API RP 500A, *Classification of Locations for Electrical Installations in Petroleum Refineries*, 1987.

API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*, 1991.

D-1.2.3 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*, 1992.

D-1.2.4 CGA Publication. Compressed Gas Association, 1235 Jefferson Davis Highway, Crystal Gateway 1, Suite 501, Arlington, VA 22202-4100.

CGA G-2, *Anhydrous Ammonia*, 1984.

D-1.2.5 U.S. Government Publication. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

Code of Federal Regulations, Title 29, Part 1910.111, "Storage and Handling of Anhydrous Ammonia."

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