

Recommended Practice for Installation and Operation of Wet Steam Generators

API RECOMMENDED PRACTICE 11T
SECOND EDITION, NOVEMBER 1, 1994

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005



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Exploration and Production Department

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FOREWORD

This recommended practice is under the jurisdiction of the American Petroleum Institute (API) Committee on Standardization of Production Equipment.

This standard shall become effective on the date printed on the cover but may be used voluntarily from the date of distribution.

Recommended Practice for Installation and Operation of Wet Steam Generators

1 Scope

1.1 INTRODUCTION

1.1.1 The Wet Steam Generator used in enhanced oil recovery is a forced circulation once-through design. It is also known by many other common names such as thermal recovery heater, oil field heater, etc. The once-through design enables the use of water essentially free of hardness and suspended solids, but of relatively high total dissolved solids. The equipment normally uses a fixed water flow system with some modulation capabilities for reduced output. The equipment does not contain drums or level controls, which are normally associated with stationary boilers. The Wet Steam Generator can be designed for installation in environments found in oil production areas of the world. Minimum operator attention is required.

1.1.2 For the most common sizes of Wet Steam Generators, field construction is held to a minimum. Most units are skid mounted and can be transported by rail, truck, or ship. The Wet Steam Generator is equipped with necessary controls and instrumentation to monitor operating pressures, flows, temperatures, etc., to protect personnel and equipment.

1.2 RATING

1.2.1 Wet Steam Generators are usually rated in millions of BTU's per hour of heat absorbed. They may also be rated by pounds per hour of steam, boiler horsepower, burner heat release capability, etc.

1.3 COMPONENTS

The basic parts of the Wet Steam Generator are as follows:

1.3.1 Feedwater System

Comprised of feedwater pumps and controls to provide a regulated quantity of water to a Wet Steam Generator.

1.3.2 Feedwater Preheater

Usually a double pipe heat exchanger. The heat source for this exchanger is normally taken from the convection section outlet. Its purpose is to elevate the inlet feedwater to a temperature above the flue gas dew point to prevent acid gas corrosion of carbon steel.

1.3.3 Convection Section

The last heat exchange area in the Wet Steam Generator to be exposed to the flue gases. The convection coil makes up most of the heating surface of the generator. The first tubes

exposed to the flue gas in the convection section are bare and are designed to reduce the gas temperatures prior to entering the finned section, and prevent luminous radiant heat on finned tubes. The convection section is normally a counter flow exchanger.

1.3.4 Radiant Section

Comprised of a combustion chamber with a serpentine radiant coil being the most common configuration. Here, the desired steam quality is obtained.

1.3.5 Fuel System

Wet Steam Generators burn a variety of fuels, the most common being natural gas or crude oil. The fuel gas system is designed with safety shutoff valves and pressure regulators. The fuel oil system normally includes safety shutoff valves, strainers, steam/oil heat exchanger, electric oil heater, pressure regulators, bypass systems, air and steam atomizing systems. The burner is designed for the required heat input, fuel and proper flame pattern.

1.3.6 Safety Equipment

Includes pressure relief and safety valves, flame safeguard equipment, and temperature, pressure and flow monitoring systems designed for safe equipment operation.

2 Specifications

2.1 This section establishes the minimum information to be furnished by the purchaser in order that minimum design, safety and environment considerations are established.

2.2 APPLICABLE AND STANDARDS

2.2.1 API

2.2.2 ASME

2.2.3 NEC

2.2.4 NFPA

2.2.5 EPA

2.2.6 ANSI

2.2.7 ASTM

2.2.8 OSHA

2.2.9 NEMA

2.2.10 State Codes

2.2.11 Local Codes

2.3 RATING AND EFFICIENCY

2.3.1 Wet Steam Generators should be rated in millions of BTU's per hour absorbed (MM BTU/Hr.) at the required discharge pressure (PSIG) and steam quality. Purchaser should specify that suppliers also state output capacity in pounds per hour of wet steam generated based on the feed-water temperature and desired steam quality specified by the purchaser.

2.3.2 Wet Steam Generator thermal efficiencies should be based on the higher heating value (HHV)* of the fuels to be burned, the specified exhaust gas temperature, and the excess oxygen or excess air in the flue gases.

2.3.3 Wet Steam Generator thermal efficiencies may also be based on the lower heating value (LHV)** of the fuels to be burned, the specified exhaust gas temperature, and the excess oxygen or excess air in the flue gases.

2.4 SPECIAL CONSIDERATIONS

Since each generator site is different, the following information should be supplied by the purchaser in the specifications to the vendor.

2.4.1 Fuel Oil Analysis—(See Table 1)

2.4.2 Fuel Gas Analysis—(See Table 2)

2.4.3 Other Fuels Analysis

2.4.4 Feedwater Analysis—(See Table 3)

2.4.5 Other Utilities Available

- a. Electrical Power _____ V. _____ Ph.
_____ Hz.
- b. Compressed Air: _____ SCFM P S I G
_____ Dew Point
- c. Pilot Fuel: _____ Type _____ SCFM
_____ PSI

2.4.6 Site Conditions

- a. Ambient Air Temp. °F: _____ Max.
_____ Min. _____ Design
- b. Wind Velocity, MPH: _____ Max.
_____ Min. _____ Design
- c. Elevation, Ft. Above Mean Sea Level: _____

- d. Seismic Zone: _____
- e. Rainfall In./Yr.: _____ Avg.

*The higher heating value of a fuel is defined as the heat evolved, as measured by a constant pressure calorimeter, when a fuel is completely burned at stoichiometric conditions and the products of combustion are cooled to 60°F and the water vapor produced is completely condensed to liquid at that temperature. Heating values are reported in BTU/SCF for gaseous fuels, BTU/Lb. or BTU/Gal. for liquid fuels and BTU/Lb. for solid fuels.

**The lower heating value of a fuel is defined as the higher heating value minus the latent heat of vaporization of the water formed by the combustion of the hydrogen in the fuel. For a fuel with no hydrogen, the lower and higher heating values are the same.

f. Humidity %: Max. _____ Min.

Design _____

g. Atmospheric Conditions

List unusual conditions such as H₂S,
Sand, Dust, Salt, Air, etc.

2.4.7 Environmental Considerations

- a. SO₂ Emission Limits,
PPM: _____ Current _____ Future
Lbs/Hr.: _____ Current _____ Future
- b. NO_x Emission Limit,
PPM: _____ Current _____ Future
Lbs/Hr.: _____ Current _____ Future
- c. Particulate Emission Limit,
Gr/SCF: _____ Current _____ Future
Lbs/Hr.: _____ Current _____ Future
- d. Waste Liquid Emission Limits

2.4.8 Transportation

List unusual transportation restrictions such as Tunnels,
Narrow Or Weak Bridges, Restrictive Roads, etc.

Table 1—Fuel Oil Analysis

Higher Heating Value (HHV)	_____	BTU/Lb.
Lower Heating Value (LHV)	_____	BTU/Lb.
Density, 60°F	_____	Lb/Ft ³
or		
Specific Gravity, 60°F	_____	
or		
API Gravity, 60/60°F	_____	
Viscosity @ 60°F	_____	SSU
122°F	_____	SSU
200°F	_____	SSU
Other _____ °F	_____	SSU
Conradson Carbon Residue	_____	% Wt.
Ash	_____	% Wt.
Carbon (C)	_____	% Wt.
Hydrogen (H)	_____	% Wt.
Sulfur (S)	_____	% Wt.
Nitrogen (N)	_____	% Wt.
Water (H ₂ O)	_____	% Wt.
Sediment	_____	% Wt.
Vanadium (Va)	_____	mg/l
Iron (Fe)	_____	mg/l
Magnesium (Mg)	_____	mg/l
Sodium (Na)	_____	mg/l
Chloride as NaCl	_____	Lb/100 Bbl.

Table 2—Fuel Gas Analysis

Natural Gas		
Higher Heat Value	_____	BTU/SCF
Lower Heat Value	_____	BTU/SCF
Molecular Weight	_____	
or		
Density, 60°F & 14.696 PSIA	_____	Fe ³ /Lb.
Temperature	_____	°F
Supply Pressure	_____	PSIG
Components (Mole %)		
Carbon Dioxide (CO ₂)	_____	%
Hydrogen Sulfide (H ₂ S)	_____	%
Nitrogen (N ₂)	_____	%
Oxygen (O ₂)	_____	%
Methane (CH ₄)	_____	%
Ethane (C ₂ H ₆)	_____	%
Propane (C ₃ H ₈)	_____	%
Butanes + (C ₄ +)	_____	%

Table 3--Water Analysis

Source:	_____
Pressure:	_____ PSIG
Temperature:	_____ °F (Min) _____ °F (Max)
Components	
*Calcium, (Ca)	_____ mg/l
*Magnesium, (Mg)	_____ mg/l
*Oxygen, (O ₂)	_____ mg/l
Barium, (Ba)	_____ mg/l
*Iron, (Fe)	_____ mg/l
*Sodium, (Na)	_____ mg/l
Copper, (Cu)	_____ mg/l
Potassium, (K)	_____ mg/l
Ammonium, (NH ₄)	_____ mg/l
*Chloride, (Cl)	_____ mg/l
Iodide, (I)	_____ mg/l
Bicarbonate, (HCO ₃)	_____ mg/l
Carbonate, (CO ₃)	_____ mg/l
Silica, (SiO ₂)	_____ mg/l
Sulfate, (SO ₄)	_____ mg/l
Hydroxide, (OH)	_____ mg/l
Hydrogen Sulfide (H ₂ S)	_____ mg/l
Organic Acids	_____ mg/l
*Total Alkalinity	_____ mg/l
*Total Hardness, (CaCO ₃)	_____ mg/l
*Total Dissolved Solids	_____ mg/l
*Total Suspended Solids	_____ mg/l
*pH _____ Specific Gravity @ 60°F _____	
*Oil _____ mg/l Resistivity @ 75°F _____ Ohm-meter	
*Minimum Data Required	

2.4.8 Transportation

List unusual transportation restrictions such as Tunnels, Narrow Or Weak Bridges, Restrictive Roads, etc.

2.5 SAFETY EQUIPMENT

The following safety instrumentation and limit switches should be supplied for fully-automatic, unattended operation and for maximum safety of personnel and equipment.

2.5.1 Safety Instrumentation & Equipment

- ASME Code Required Safety Valve(s).
- Electronic Flame Monitoring Device and Combustion Controller including pre-purge, proof-of-pilot, proof-of-main flame, and post-purge sequence.
- Steam pressure controller
- Feedwater Flow Rate Transmitter & Controller
- Feedwater Pump Relief Valve
- Burner Firing Rate Controller
- Appropriate Temperature and Pressure Indicating Devices

2.5.2 Operating Safety Limits

The following safety limit devices are recommended, each limit should shut burner fuel valve(s) and require manual restart after malfunction:

- Flame Failure
- High Steam Pressure
- High Steam Pressure
- High Tube Temperature
- High Stack Temperature
- High Burner Throat Temperature (oil fired only)
- Burner Throat Switch (swing-out burners only)
- High/Low Atomizing Pressure (oil fired only)
- High Fuel Gas Pressure (gas fired only)
- Low Fuel Oil Pressure (oil fired only)
- Low Fuel Oil Temperature (oil fired only)
- Low Feedwater Flow Rate
- Low Combustion Air Pressure
- Low Instrument Air Pressure
- Low Steam Pressure
- Power Failure

2.6 AESTHETICS

Special consideration should be given to the locale of the Wet Steam Generator installation. The following should be considered:

2.6.1 Installation Housing**2.6.2 Installation Color Scheme**

*Minimum required by Federal and most state codes. Others may be required by some states or insurance codes.