Training Module

Describe and Operate Indirect-Fired Line Heaters

HDC Human Development Consultants Ltd.

Cover Photo
Courtesy of Presson ENERFLEX and Petro-Canada

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Website: **www.hdc.ca**
E-mail: **marketing@hdc.ca**
Phone: **(780) 463-3909**

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Training Objectives

Upon completion of this training kit, you will be able to:

- Describe the purpose and importance of indirect-fired line heaters
- Describe line heater:
  - components and their function
  - combustion safety controls
- Describe line heater site layouts
- Describe line heater site systems and equipment
- Describe line heater safety
- Describe manual lighting of line heater burner
- Describe line heater operating variables and operations monitoring
- Troubleshoot line heaters

1 Introduction

Indirect-fired line heaters are used to heat natural gas before the gas is shipped by pipeline for processing or for distribution to residential and industrial customers.

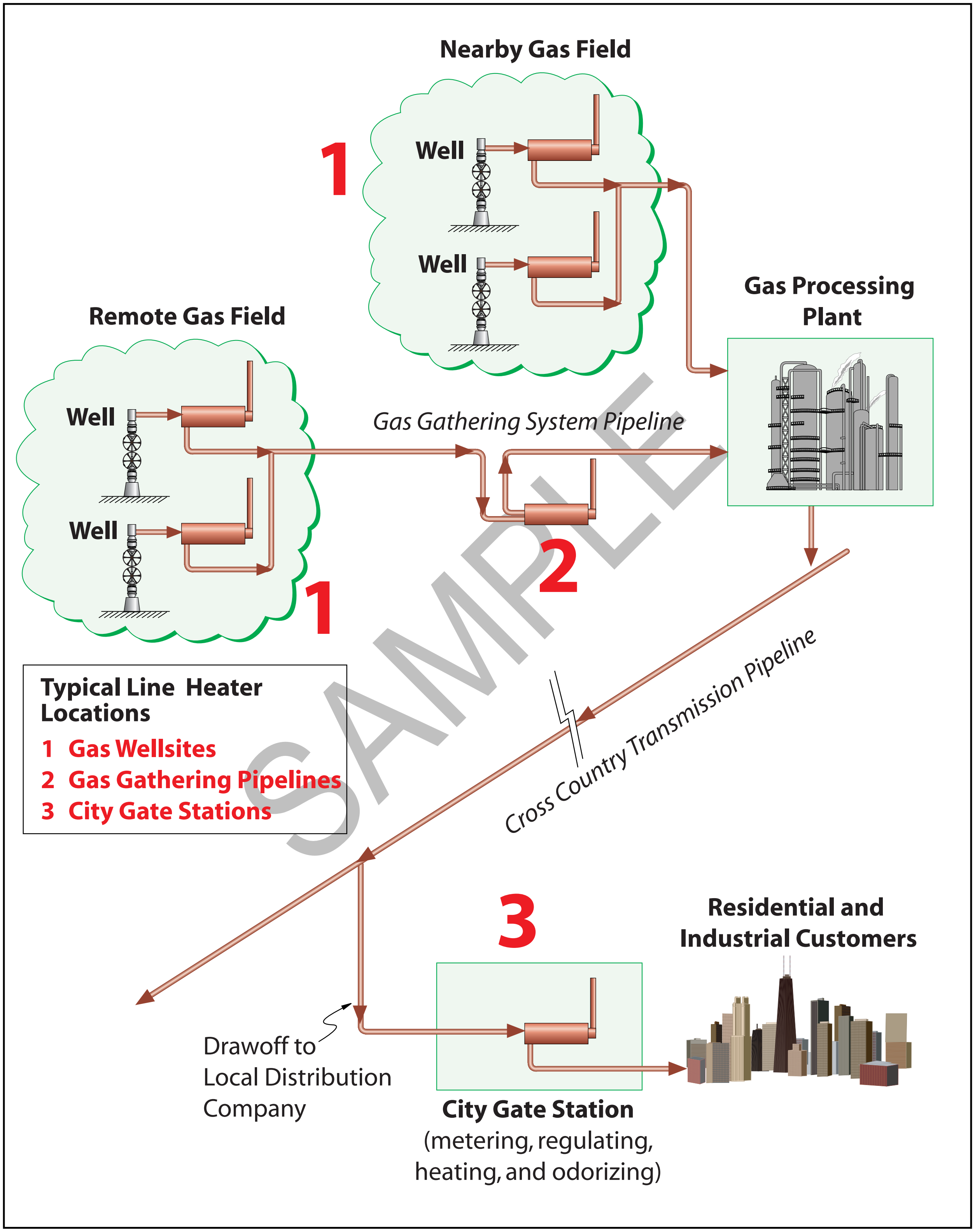
During shipping, processing, and distribution, the natural gas cools as:

- heat is lost to cooler surroundings (e.g., a subsurface gas pipeline loses heat to the surrounding soil)
- the pressure of the gas is reduced

Gas cooling can cause problems downstream on the pipeline:

- the formation of hydrates which can block the pipeline (see the textbox on page 4 about hydrates and their hazards)
- hydrates formed in meters can cause inaccurate readings
- the chilling of downstream equipment:
  - in mechanical equipment (e.g., meters, regulators, and valves), cold temperatures may prevent lubricated internal components from operating effectively
  - in gas analysis instrumentation, cold temperatures may contribute to inaccurate sampling results

Figure 1—Typical Line Heater Locations in Natural Gas Processing/Distribution



Indirect-fired line heaters heat the natural gas to prevent hazardous hydrate blockages and frozen downstream equipment.

Line heaters are typically installed:

- at gas wellsites where the high wellhead pressure must be reduced so that gas can flow via lower pressure piping to a downstream gas plant. A major drop in gas pressure causes significant cooling of the gas to the point where hydrates could form. Line heaters are installed at the site to heat the gas to prevent hydrate formation.
- along gas gathering system pipelines that link remote gas fields to gas processing plants. Gas cools as it passes through the pipeline and loses heat to the surrounding subsoil. Line heaters along gas gathering system pipelines reheat the gas to prevent hydrates from forming.
- at city gate stations where local distribution companies purchase, meter, regulate, and odorize the processed natural gas received from transmission pipelines. The city gate station's pressure regulators reduce the gas pressure from its high transmission line pressure to the lower local distribution line pressure. Line heaters at city gate stations provide enough heat to prevent chilling of downstream equipment.

This module focuses on the operation of indirect-fired line heaters at gas wellsites and along gas gathering system pipelines.

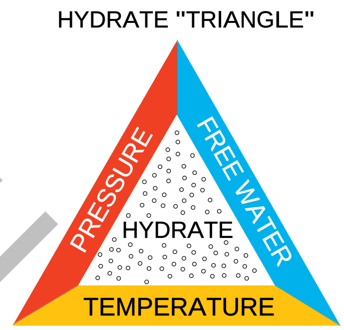
Figure 2— Indirect-Fired Line Heater at Wellsite (*Courtesy of Presson ENERFLEX and Petro-Canada)*

Hydrates and Their Hazards

Hydrates are a mixture of water and gas that forms crystals under certain temperature and pressure conditions. In a hydrate, gas molecules (such as methane, ethane, propane, butane, hydrogen sulphide, and carbon dioxide) are embedded inside a lattice of water molecules. Hydrate crystals deposit on solid surfaces and restrict gas flow. Hydrates can plug valves, meters, instruments, and flow lines.

Hydrates:

- can form at high pressure, even when the temperature of the flowing gas is above the freezing point of water
- can form when free water condenses in the gas stream
- tend to form at sharp bends in flow lines and at locations where the pressure drops. However, hydrates can occur anywhere the temperature drops below the hydrate formation point.



Hydrate formation can be prevented by:

- operating at high gas temperatures
- operating at low gas pressures
- operating at a lower water content
- injecting a hydrate inhibitor, such as methanol

Preventing hydrates from forming is important:

- Clearing hydrate blockages is a high-risk activity. Incorrect hydrate removal can cause pipeline/equipment rupture and put people in harm's way.
- Hydrate blockages interrupt business: a hydrate blockage means that gas is unable to flow.

Indirect-Fired Line Heater—Operating Principle

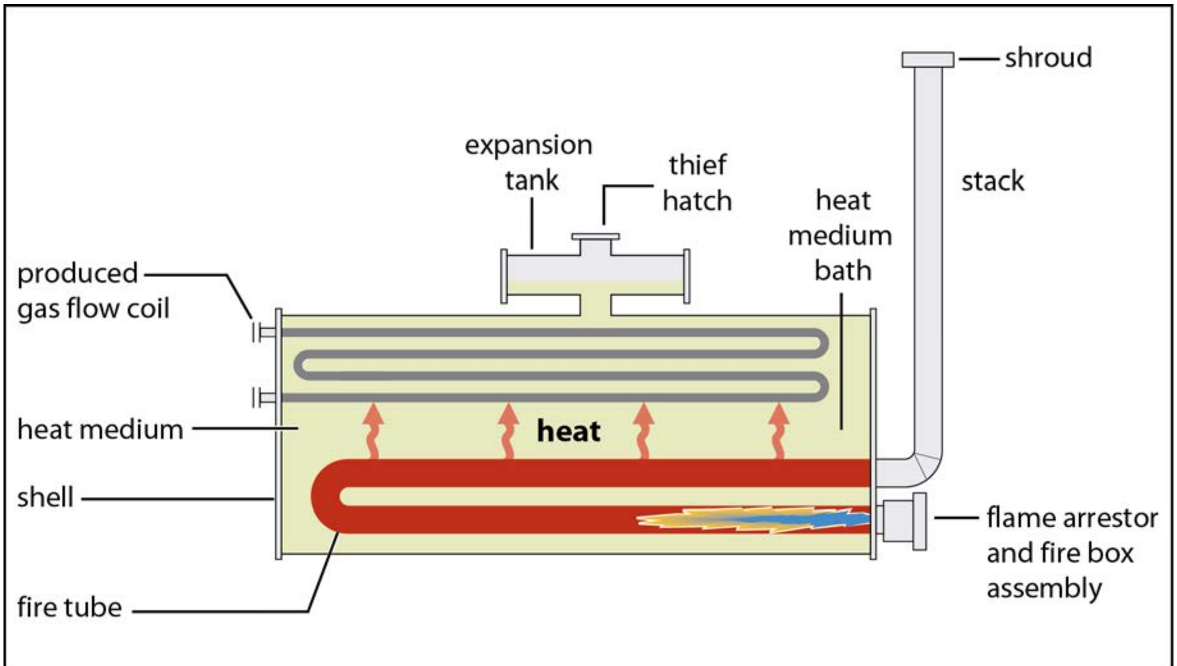
In an *indirect*-fired line heater, a fire tube immersed in a heat medium (HM), such as glycol, heats the HM (Figure 3). The natural gas passes through a flow coil that is also immersed in the HM bath and is heated indirectly.

In a *direct*-fired line heater, the fire tube is immersed in the product being heated.

NOTE

In this module, the terms *line heater* and *heater* refer only to indirect-fired line heaters.

Figure 3—Line Heater Operating Principle



The fire tube heats the HM bath as follows:

- A fire tube is submerged in the lower part of the HM bath. A flame travels down the fire tube and transfers heat to the HM. Cooled combustion gases flow from the fire tube and rise up a stack.
- As the HM's temperature increases, its density decreases to create thermal circulation in the bath:
  - Hot, less dense HM rises to the upper part of the shell.
  - The gas flowing in the gas flow coil absorbs heat from the HM.
  - The HM's temperature decreases and its density increases. The cooled HM sinks to the bottom of the shell to be reheated.

Line Heater Application and Site Requirements

A line heater must be appropriate for site conditions: it must be able to heat the gas enough to prevent hydrate formation.

Line heaters are usually skid-mounted and can be transferred between sites. Before a line heater is transferred to a new site, your company will ensure that:

- the heater's design specifications match conditions at the new site
- the heater and its components comply with regulatory requirements for the new site

This module describes line heaters that are correctly designed for site conditions and meet regulatory requirements.

Indirect-Fired Line Heater—Operator's Role

Careful monitoring and control of indirect-fired line heaters contribute to the safe and efficient operation of the heater and prevents hydrate formation in downstream piping. Operations include:

- monitoring operating variables (temperature, pressure, bath level, flow) to assess/optimize heater operation
- starting up and shutting down the heater
- troubleshooting heater problems and rectifying minor problems
- promptly reporting major problems

Additional Operator responsibilities are described in Section 10.

Module Contents

For indirect-fired line heaters, this module describes:

- heat medium components
- combustion components
- combustion safety controls
- site layouts
- site systems and equipment
- safety
- line heater burner lighting
- operating variables and operations monitoring
- troubleshooting

2 Heat Medium Components

This section describes the indirect-fired line heater's shell and produced gas flow coil.

NOTE

In this module:

- the term *produced gas* refers to the natural gas flowing through the coil and being heated
- the term *fuel gas* refers to the gas that fuels the burner
- the term *instrumentation gas* refers to the natural gas or propane used to operate pneumatic controls

2.1 Heater Shell

The heater shell is a horizontal, cylindrical vessel that operates at atmospheric pressure. The shell holds the large volume of HM that transfers heat from the fire tube to the produced gas flow coil. The heater shell has two end flanges:

- the produced gas flow coil is installed through one end flange
- the fire tube is installed through the other end flange

WARNING

For colder climates, the shell may be insulated. On older line heaters, asbestos may have been used for insulation. Follow your company procedures for handling asbestos.

Expansion Tank

The heater shell has a top expansion tank (also called a *surge tank* or *reservoir*). The tank has sufficient volume:

- to ensure that the heater shell is completely filled with HM (i.e., the liquid fully covers the produced gas flow coil)
- to accommodate HM expansion when the HM temperature increases during cold startup

The expansion tank has a top hatch (thief hatch) that serves as both an HM fill port and a vent/breather. Because the shell can only withstand atmospheric pressure, the hatch's vent/breather provides both overpressure and vacuum protection:

- Venting prevents shell rupture:
  - During line heater startup, the HM is heated to operating temperature and expands. Air is pushed out the hatch.

  - In case the flow coil ruptures, venting protects the shell from overpressure rupture.
- Breathing prevents shell vacuum collapse. After the line heater is shut down, the HM cools and contracts. Air is drawn in through the hatch to compensate for the decrease in HM volume.

NOTE

For line heaters that have *water* baths, the expansion tank minimizes water vapor loss. This type of expansion tank is known as a *water saver*. The lower temperature at the top of the expansion tank condenses the steam rising off the liquid surface.

Heating Medium

The HM is either water or a glycol-water solution. A glycol-water mixture has a lower freezing point and a higher boiling point than water. The type of HM used depends on the climate and required heating:

- **Water** is used in hot climates where the HM does not have to be protected from freezing. When using a water bath, a line heater is operated below water's boiling point to protect against boiling off the bath water.
- **Distilled water** may be used in colder climates. Compared to water with impurities, distilled water freezes at a lower temperature.
- **Glycol-water** bath solutions are used:
  - in cold climates where the bath must not freeze (in case the line heater shuts down during cold weather operations)
  - in any climate where a high bath temperature is required

The water and glycol-water solutions used in line heaters are treated with corrosion inhibitors to prevent internal fouling and corrosion. Your company may stipulate that:

- a specific glycol-water mixture be used instead of vehicle antifreeze
- HM be sampled regularly to verify glycol/water concentration, freezing/boiling points, and corrosion inhibitor strength

The level of the heat medium is determined by two factors:

- The fire tube and gas flow coils must be covered
- Some empty space is required for thermal expansion

Follow the manufacturer's recommendations for the required level of the heat medium.

2.2 Produced Gas Flow Coil

The produced gas flow coil (also called the tube bundle) is a removable length of piping installed above the fire tube in the HM bath. Pressurized produced gas from the wellhead or pipeline is directed through the flow coil for heating.

The gas flow coil must always be completely submerged in the HM during line heater operation. Keeping the coil submerged ensures that the produced gas in the coil is effectively heated. The coil must remain submerged even after the line heater is shut off and has cooled. Remaining submerged ensures that the coil is not exposed to the corrosive effects of the air (drawn in through the vent/breather during cool down).

Engineering and/or regulatory codes dictate how the produced gas flow coil is manufactured, pressure-tested, and re-tested/ inspected during the coil's service life to ensure the coil can withstand the high gas pressures.

The configuration of the coil depends on both:

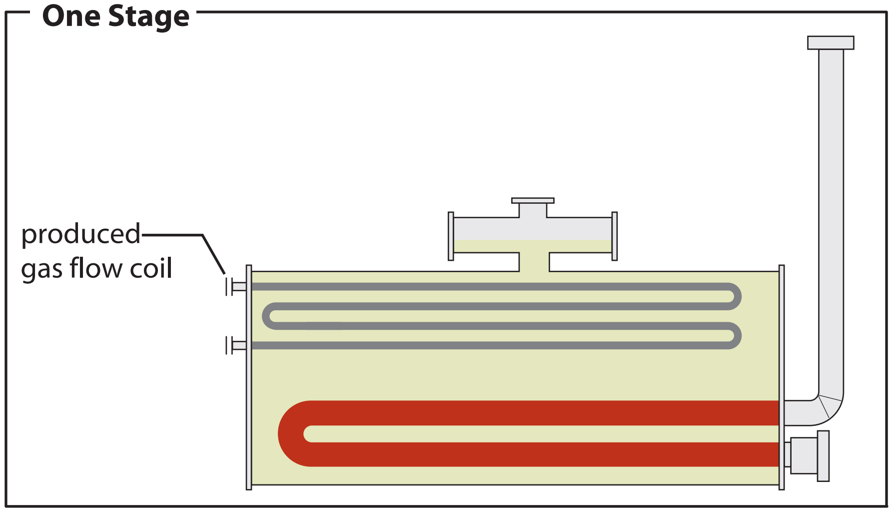
- the number of heating stages needed by the produced gas heating application (either one or two stages)
- the number of coils needed to handle the produced gas flow rate (either one coil for low flow rates or multiple parallel coils for higher gas flow rates)

Heating Stages

One heating stage is used on line heaters which must provide only a moderate temperature increase (such as those on gathering system pipelines).

Figure 4 on the following page show a one heating stage line heater.

Figure 4—One-Stage Produced Gas Flow Coil



Two heating stages are used on line heaters which must provide a great amount of heating to counter the intense cooling caused by a large pressure reduction. (Large pressure reductions commonly occur at sites where the wellhead gas pressure must be reduced to match lower gathering system pressure.) On two-stage line heaters (see Figures 5 and 6), the coil provides a preheating stage *before* the pressure reduction and a reheating stage *after* the pressure reduction. (Preheating the gas before a large pressure reduction ensures that the cooling caused by the pressure drop does not chill the gas to below hydrate-formation temperature.)

The produced gas flows through the two-stage heater as follows:

- the produced gas flow enters the preheat coil and is heated
- the heated produced gas flow leaves the preheat coil and passes through the pressure reduction valve (choke)
- after pressure reduction (and resulting cooling), the produced gas flows into the line heater's reheat coil, is heated to the final temperature, and then exits the line heater. (The reheat coil is also known as the post-heat coil.)

For line heaters equipped with preheat and reheat coils:

- The preheat coil is built to withstand higher pressure than the reheat coil.
- The configuration of the pressure reduction valve (choke) between the preheat and reheat coils can vary:

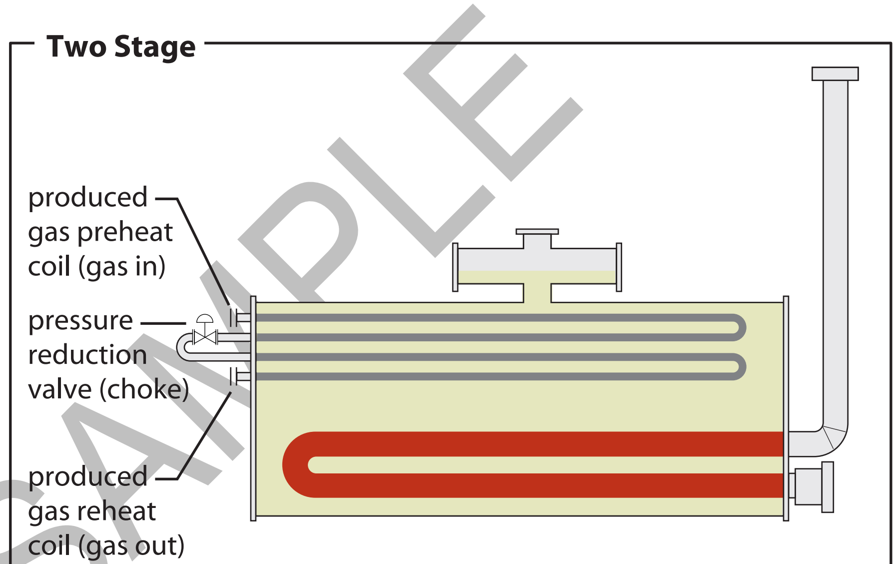
- — The valve may be a manual valve whose body is immersed in the HM bath.
- — The valve may be an external control valve that is automatically positioned as part of a wellhead pressure control or flow control strategy to maintain flow and/or pressure setpoint (as described in Section 6).

NOTE

For a detailed description of process control and control loop strategies, refer to these HDC training kits:

- *Describe Basic Instrumentation and Control Strategies*
- *Describe Process Control Modes and Process Control Technology*

Figure 5—Two-Stage Produced Gas Flow Coil



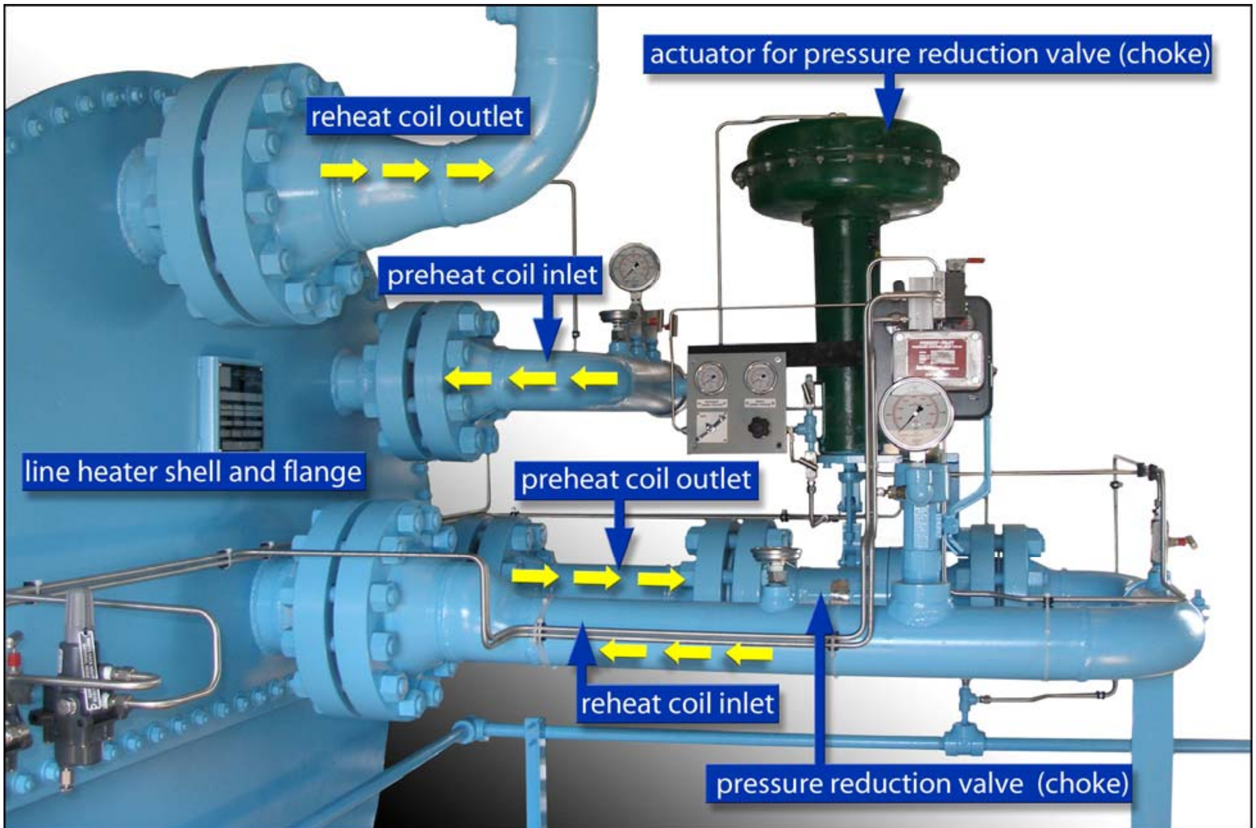
Refer to the next page for a picture of a two stage gas coil and choke.

Number of Produced Gas Coils

Depending on the gas flow to be heated, a line heater's produced gas coil may consist of a single coil or multiple, parallel coils:

- **single coil**. A single coil may be sufficient to heat a small gas flow. A single coil is configured as a spiral-wound bundle or as a tube-type bundle (where the coil makes numerous passes back and forth before leaving the line heater).

Figure 6—Line Heater with Two-Stage Produced Gas Coil and Choke
(Courtesy of Larsen & D'Amico Mfg. Ltd.)



- **multiple, parallel coils**. To heat a large gas flow, the flow to the line heater branches outside of the heater to feed multiple, parallel, tube-type coils. After passing through the heater, the flows recombine.

3 Combustion Components

The burner directs a flame into the submerged fire tube to heat the HM. The following components support the heater's combustion operation (see Figure 7):

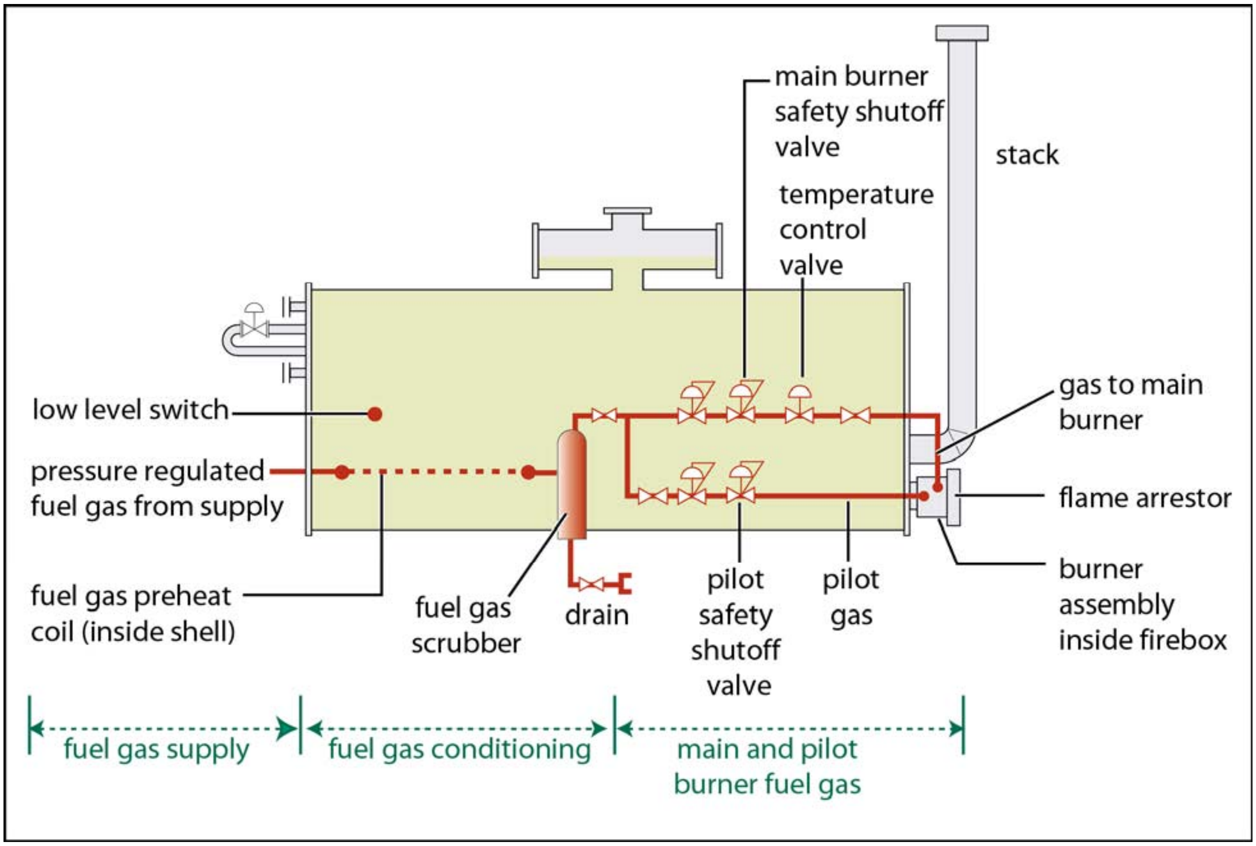
- fuel gas supply
- fuel gas conditioning system
- burner fuel gas train
- burner assembly
- fire tube assembly
- flame arrestor/wind box

3.1 Fuel Gas Supply

A line heater needs a reliable source of fuel gas. The fuel gas source may be:

- a drawoff from the line heater produced gas outlet
- a natural gas utility distribution network or nearby gas processing plant
- a propane storage system

Figure 7—Line Heater's Combustion Components



Drawoff from Line Heater Outlet

The produced gas heated in the gas flow coil may be of sufficient quality to support efficient combustion. In this case, a slipstream of heated produced gas is withdrawn downstream of the line heater. The produced gas may contain toxic contaminants at trace levels that do not impair reliable combustion. However, some contaminants are hazardous/toxic, even at trace levels. Refer to Section 8.3 for safety precautions at line heater sites.

In applications where produced gas is used as the fuel gas source, the fuel gas drawoff may be equipped with:

- a manual isolation block valve
- a pressure regulator to reduce the gas pressure

WARNING

When produced gas is used as fuel gas, the fuel gas typically does not contain a leak detection odorant. Although the fuel gas may have a petroleum odor, don't assume that you will be able to smell a fuel gas leak.

Natural Gas Utility or Nearby Gas Plant

If the produced gas is not suitable, fuel gas may have to be supplied from offsite. Two sources are:

- commercial-quality natural gas piped from a gas utility distribution network
- sales-quality natural gas from a nearby gas plant

NOTE

At some remote gas plants, a slipstream of sales gas is withdrawn to supply equipment in the surrounding gas fields.

In applications where the fuel gas arrives from offsite, the fuel gas piping may be equipped with:

- a manual isolation block valve
- an ESD (emergency shutdown) valve to close automatically in case of a site emergency
- a pressure regulator to reduce the gas pressure to an intermediate pressure
- a flowmeter to record fuel gas consumption

WARNING

Find out if the fuel gas at your site is odorized:

- Fuel gas arriving from an offsite location may contain a leak detection odorant.
- Fuel gas from a gas utility is typically odorized, whereas fuel gas from a gas processing plant may not be. Don't assume that you will be able to smell a fuel gas leak.

Propane Storage System

If the produced gas is not suitable for use as fuel gas, another option is to use propane supplied from a storage system. The propane storage system consists of an outdoor propane storage tank that holds a large volume of liquid propane under pressure. The propane is withdrawn from the tank using either:

- propane *liquid* drawoff (for larger capacity systems)
- propane *vapor* drawoff (for smaller capacity systems)

Propane Liquid Drawoff

Propane liquid flows or is pumped from the bottom of the tank through the tank's manual liquid isolation valve. The propane liquid is then heated in a specialty heater known as a propane vaporizer.

Propane Vapor Drawoff

Propane vapor leaves the top of the tank through the tank's manual isolation valve and is directed through a regulator to reduce the propane pressure.

A propane tank configured to supply propane vapor may have difficulty supplying sufficient vapor during cold weather. A propane tank's ability to discharge vapor declines as the outdoor temperature drops and the tank's propane level drops. To prevent an interruption in propane vapor flow, the propane tank may be winterized with an external flameless heater (a catalytic heater, described in Section 7.1). The heater provides radiant heat to the tank's wall to ensure sufficient propane vapor.

Propane System Monitoring

The Operator checks the propane system to ensure continued fuel gas supply:

- monitors propane storage tank pressure and requests a propane refill, if necessary
- confirms that the propane system's valves are correctly configured
- during the winter, confirms the operation of the propane tank's heater and flow of propane vapor from the tank

WARNING

At sites where propane is used as fuel gas, your personal combustible gas detector must be able to detect:

- propane fuel gas leaks
- methane produced gas leaks

Consult your company's health and safety practices.

3.2 Fuel Gas Conditioning System

All fuel gas undergoes conditioning (see Figure 7):

- fuel gas preheating
- fuel gas scrubbing
- additional fuel gas filtration

Fuel Gas Preheating

The fuel gas passes through a preheat coil immersed in the HM bath. After heating, the fuel gas flow branches and flows through pressure regulators in the main burner and pilot burner supply lines. Preheating the fuel gas before it flows through the pressure regulators prevents hydrates from forming.

Fuel Gas Scrubbing

Liquids entrained in the fuel gas must be removed to prevent:

- poor burner operation; the liquids may not burn consistently:
  - the burning liquids may produce a smoky flue gas exhaust
  - the liquids may not burn and may pool at the bottom of the firebox housing. This pooled liquid may drain out of the firebox flame arrestor, creating a fire hazard. The pooled liquid may suddenly ignite or explode.
- discharge of flammable droplets out the top of the flue stack which may ignite surrounding vegetation
- liquid entry into instrumentation lines. Liquids interfere with the operation of pneumatic controls and instrumentation.

The fuel gas scrubber is a small separator where liquids in the incoming fuel gas settle to the bottom and the gas rises to the top outlet.

In case of a high liquid level in the scrubber, the scrubber's protective controls stop the flow of fuel gas, shutting down the line heater burner. The scrubber's high level protective controls may consist of:

- an internal float ball that rises with the liquid until the ball seals off the scrubber's fuel gas outlet
- a float level switch that is triggered at a preset liquid level to stop the flow of fuel gas by closing a shutoff valve.

The scrubber's drain valve depends on the liquid content of the fuel gas:

- At sites where the fuel gas normally contains liquid, the scrubber has a drain valve that automatically opens at a preset level to empty the scrubber to a liquid drain system.
- At sites where the fuel gas does not normally contain liquids, the scrubber may have only a manual drain valve. Because liquid accumulation in the scrubber is abnormal, any liquid would be drained manually to a portable container and disposed by the Operator. The Operator must perform liquid drainage/disposal in accordance with company safety procedures and company/regulatory waste/effluent disposal policies.

The fuel gas scrubber has a pressure safety valve (PSV) that opens to relieve excessive pressure to prevent scrubber rupture. Overpressurizing of the scrubber can be caused by upstream regulator failure.

Additional Fuel Gas Filtration

Some line heaters may be equipped with fuel gas filtration, depending on the contaminant(s) to be removed:

- To remove solids, a metal mesh strainer or a particulate filter is used. The strainer's removable mesh element can be cleaned and reinstalled; a particulate filter's internal elements are replaceable.
- To remove liquid mist, a coalescing filter is used. The coalescing filter's elements are replaceable.

3.3 Burner Fuel Gas

The burner fuel gas piping/valving assembly:

- receives conditioned fuel gas
- branches to direct the fuel gas to the heater's main burner and pilot burner
- controls the flow of fuel gas to ensure safe operation of the heater's main burner and pilot burner

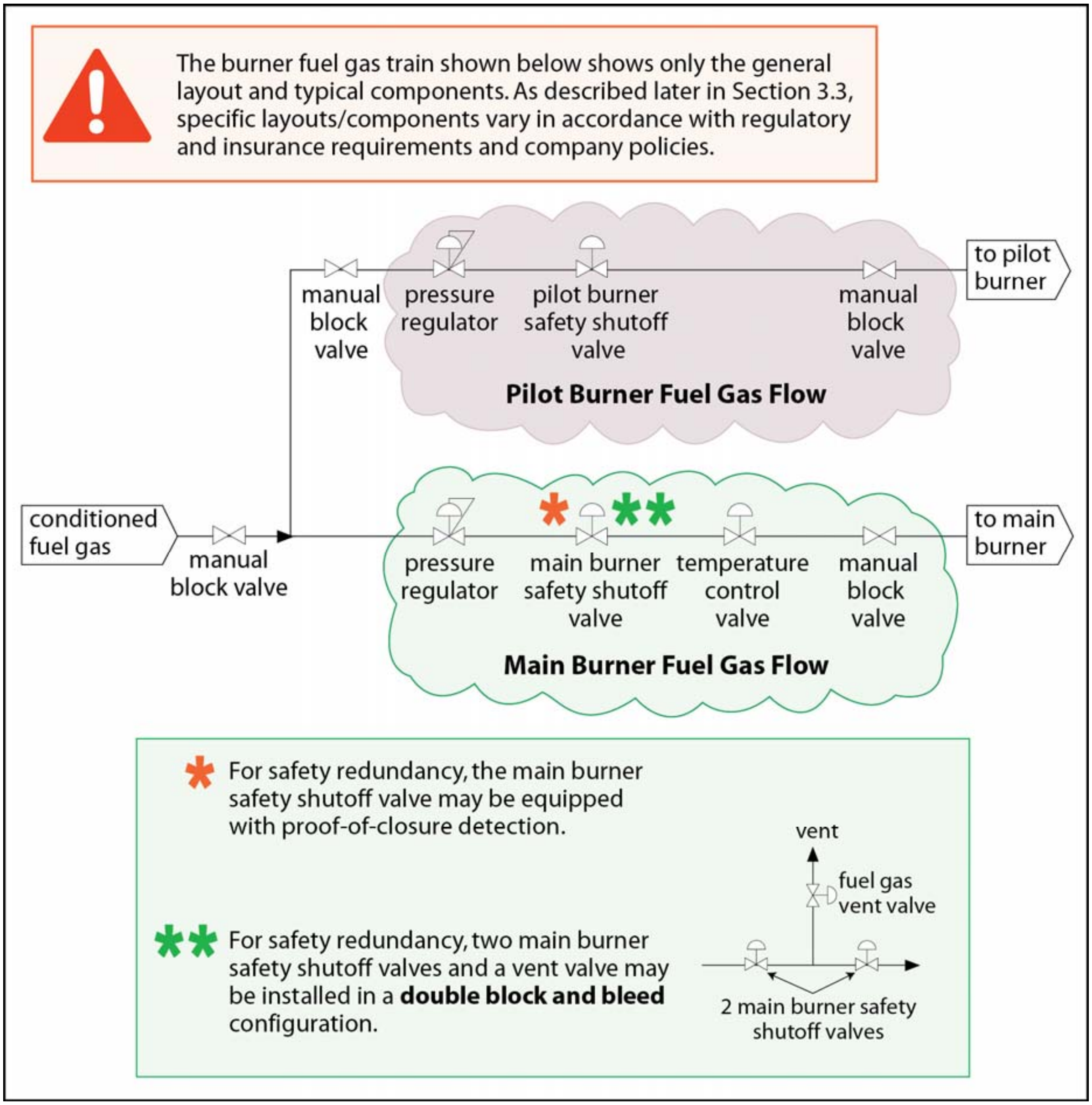
The specific fuel gas valving/control configuration is determined by regulatory and insurance requirements and company policies.

The more stringent requirements incorporate a higher level of:

- safety redundancy
- burner safety controls to automate burner operation and the burner's safe startup/shutdown
- instrumentation to enable local and remote monitoring

This section describes fuel gas valving; Section 4 describes how the valving is controlled as part of safe line heater operation, startup, and shutdown. Figure 8 shows the main burner and pilot burner fuel gas flows.

Figure 8—Main Burner and Pilot Burner Fuel Gas Flows



Fuel Gas Flow to the Main Burner

Conditioned fuel gas flows to the burner fuel gas train and passes through the following components to feed the main burner:

- **a manual block valve** used to isolate the line heater from the fuel gas supply when the line heater is shut down
- **a pilot gas drawoff**. As described later, this drawoff may be located either upstream or downstream of the burner safety shutoff valve.
- **a pressure regulator** that reduces the fuel gas pressure to the optimum main burner pressure. The regulator is typically equipped with a pressure gauge.
- **one or two main burner safety shutoff valves** that automatically closes to shut off the fuel gas flow during abnormal operation. Shutting down the flow prevents an accumulation of fuel gas, which could lead to a line heater explosion. Abnormal operation includes: