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1. Overall update.
2. IP References changed to corresponding GPs
3. Consistency check performed with EMCC's Best Practice for Fuel Systems
4. Updates from Gas Turbine and HRSG Fuel Flexibility Guide (EE.10E.2000)
5. Updates from hMobil tutorials on Fuel Gas Systems (EPT 04-T-13) and Heavy Fuel Oil Systems (EPT 04-T-08)
6. Addition of reliability check list

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SCOPE

This Design Practice (DP) presents the criteria and procedures for the design of process plant fuel systems. The systems covered are fuel oil, fuel gas and pilot gas. It is not intended to imply that these are the only fuel system configurations possible. The type of system selected depends on many factors, such as economics, type and source(s) of fuel and consumer requirements.

This Design Practice does not cover instrumentation and controls for furnaces and boilers, burner selection criteria, or design details for onsite facilities.

REFERENCES

DESIGN PRACTICES

- [Section II](#), Design Temperature, Design Pressure and Flange Rating
- [Section V](#), Drums
- [Section VIII-F](#), Fired Heaters (Burners)
- [Section IX](#), Heat Exchange Equipment
- [Section X](#), Pumps
- [Section XI](#), Compressors
- [Section XII](#), Instrumentation
- [Section XIV](#), Fluid Flow
- [Section XV](#), Safety in Plant Design
- [Section XVI](#), Thermal Insulation

OFFSITE DESIGN PRACTICES

- [Section XXII](#), Storage Facilities / Systems
- [Section XXVI](#), Steam Facilities
- [Section XXX](#), Electrical Power Facilities

GLOBAL PRACTICES

- GP 01-01-01, Drawings, Diagrams, and Line Lists
- GP 03-04-01, Piping for Fired Equipment
- GP 07-02-01, Industrial Boilers
- GP 07-04-01, Burners for Fired Heaters
- GP 09-01-01, Spacing and Dikes for Storage Vessels and Tanks
- GP 15-01-01, Instrumentation for Fired Heaters

OTHER EXXONMOBIL REFERENCES

- ExxonMobil Blue Book
- ExxonMobil Refinery Construction Materials Manual
- Gas Turbine and HRSG Fuel Flexibility Guide (EE.10e.2000)

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BACKGROUND

Process plant fuel systems are mainly collection and distribution systems. Fuels are collected from various sources within the plant and distributed to consumers at the required pressure, temperature and flow rate. Fuel consumers are typically process furnaces, boilers, incinerators, gas turbines, and gas engines.

The basic design considerations and equipment will be illustrated using typical fuel oil/fuel gas systems. By necessity, these systems are somewhat less complex in terms of the number of producers and consumers than normally found in a plant. However, the principles and considerations are applicable to all fuel systems.

DEFINITIONS

ATOMIZERS

Atomize liquid fuel into small droplets for rapid and complete combustion. Normal atomizing medium is steam but other means are available in the absence of steam. Refer to [DP VIII-F](#) for considerations and design criteria.

CONTINUOUS PILOT

A pilot that burns throughout the entire period the unit is in service, whether or not the main burner is firing.

DESULFURIZATION

A treating process that removes sulfur compounds from a petroleum stream.

DEW POINT

The temperature at which a vapor starts to condense when it is cooled. Of special concern is the dew point of the sulfuric acid in the flue gases produced when burning fuels containing sulfur (normally referred to as "acid dew point").

FIRM CAPACITY

Total installed capacity minus spare equipment.

FUEL GAS

Any combustible gas used as a source of energy in a process plant. Typical heating value of refinery fuel gas is about 1000 Btu/SCF (37,000 kJ/m³).

FUEL OIL SYSTEM

A system which is designed to distribute any combustible liquid hydrocarbon that is designated as plant liquid fuel. These liquid fuels may range from naphthas to residuum.

GII

General Instructions and Information Design Specification. Lists plant utility, process and environmental conditions.

HIGHER HEATING VALUE (HHV)

The theoretical gross heat available from the combustion of fuel, assuming the water formed by combustion is condensed. HHV is usually expressed as Btu/lb (kJ/kg).

INTERMEDIATE BTU/JOULE GAS

A fuel gas typically in the 200-400 Btu/SCF (7,500-15,000 kJ/m³) range produced from coal or residual petroleum products via an oxygen blown gasification process.

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INTERMITTENT PILOT

A pilot that burns during light-off of the main burner and while the main burner is firing, but which shuts off with the main burner.

INTERRUPTED PILOT

A pilot that burns during light-off of the main burner and is then shut off.

INSTALLED CAPACITY

The total available capacity of a system or component.

LIQUID FUEL

Any combustible liquid hydrocarbon used as a source of energy in a process plant fuel oil system.

LOW BTU/JOULE GAS

A lean fuel gas typically in the 100–150 Btu/SCF (3700 - 5600 kJ/m³) range produced from coal or residual petroleum products via an air blown gasification process. As pertaining to FLEXICOKING, a fuel gas produced by steam/air gasification of process-produced fluid coke with a LHV of approximately 110 Btu/SCF (4100 kJ/m³).

LOWER HEATING VALUE (LHV)

The net heat available from the combustion of fuel, assuming that the water formed by combustion remains in the vapor state. LHV is usually expressed as Btu/lb (kJ/kg). Fuel balances are typically done on a LHV basis.

LIQUEFIED PETROLEUM GAS (LPG)

Light hydrocarbon material, gaseous at atmospheric temperature and pressure, held in the liquid state by pressure and/or refrigeration to facilitate storage, transport and handling. Commercial liquefied gas consists mainly of propane and/or butane.

MARGINAL FUEL

The fuel source that balances the fuel demand. The control system will be designed to regulate the fuel flowrate from this liquid or gas source to maintain the fuel gas system pressure. Liquid fuel may be used as the marginal fuel by increasing the fuel oil firing to reduce the fuel gas consumption or vice versa.

MIDDLE DISTILLATES

Distillates whose boiling ranges lie between those of kerosene and lubricating oil. These include light fuel oil and diesel fuel.

NAPHTHA

A general term applied to low-boiling liquid petroleum products, ranging from butane to 430°F (221°C) final boiling point.

PITCH

The residuum from the distillation of crude petroleum, natural asphalts, etc. (a virgin product). Where pitch and tar are used as fuel, these systems operate at high temperature.

RESIDUAL FUEL OIL

A petroleum product intended for combustion in large industrial installations, composed mainly of pitch, tar and the bottoms from distillation processes, with enough lighter oil added to give a product of satisfactory viscosity.

RESIDUUM

The material remaining as non-vaporized liquid or solid from processes involving distillation or cracking (often abbreviated to "resid").

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SOUR GAS

Hydrocarbon gas containing malodorous sulfur compounds, such as sulfides and mercaptans. The most prevalent of these compounds are hydrogen sulfide and methyl mercaptan.

SWEET GAS

Hydrocarbon gas that is relatively free of sulfur compounds.

TAR

The bottom product from any cracking operation (a non-virgin product).

TURNAROUND

The period during which an entire process unit is off stream for inspection and repair.

TURNDOWN

Capability of equipment to operate at lower than design capacity. Turndown is typically expressed as a ratio of Maximum Design Capacity to Minimum Operating Capability.

VISCOSITY

Viscosity is the measurement of a fluid's resistance to flow. Since viscosity varies with temperature, its value is meaningless unless the temperature at which it is determined is reported. For liquids, viscosity decreases with increasing temperature. The opposite is true for gases.

There are many methods of determining viscosity and therefore different units of reporting are used. The more customary unit of kinematic viscosity is the centistoke (cSt). Other units of viscosity are Saybolt Universal, Saybolt Furol, Engler, and Redwood.

In designing liquid fuel systems, viscosity plays a major factor as related to pumpability and atomization at the burners. Heating of the liquid fuel is often required to achieve and maintain design requirements.

WOBBE INDEX

A measure of Btu/sec (Joule/sec) that can pass a given orifice. In addition to the heating value of the fuel, it also considers the effects of specific gravity and temperature. Therefore, it is a better indication of heat input to combustion equipment than heating value alone. Acceptable variation in Wobbe Index should be obtained from the combustion specialist or the equipment manufacturers (for boilers, gas turbines, etc.).

$$\text{Wobbe} = \frac{\text{LHV}}{\sqrt{\text{SG} \times \text{Temp}}}$$

SYSTEM TYPES AND APPLICATION

Typical fuel oil and fuel gas systems are shown in [Figures 1 and 2](#), respectively. A low Btu/Joule gas system is shown in [Figure 3A](#). Although not interconnected, the oil and gas systems are interrelated since individual furnaces and boilers can in many cases fire both oil and gas, either separately or simultaneously. Thus, the total refinery fuel requirements are shared by each system according to the respective fuel availability and consumer demand. In addition, a pilot gas system is also required.

The symbols and nomenclature used in the figures are defined in GP 01-01-01. A brief description of each of these three systems follows.

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DESCRIPTION OF A FUEL OIL SYSTEM

Liquid fuel is supplied from process units, blending systems, product tankage or a combination thereof. More than one source is usually provided for increased reliability. A fuel oil tank or surge drum provides reserve holdup for use during emergencies or system upsets.

Pumps distribute fuel oil to process and offsite consumers at the required operating conditions. Normally, a looped distribution network is provided. Looping (e.g. with recirculation) is not required for lighter liquid systems such as naphtha and kerosene. Lighter (more volatile) fuel systems also require special attention with regard to burner selection and general safety precautions (as detailed in [DP Section VIII-F](#)). Typically, two 100% capacity fuel oil pumps with different types of drivers are provided. The spare pump will start automatically if the system pressure falls below a preset level. The looped distribution network keeps fuel temperatures in all parts of the system high enough to avoid plugging and to maintain a constant viscosity at the burners. The network contains sufficient valves and blinds to allow system components, individual consumers or groups of consumers to be isolated for maintenance.

A pressure control valve located downstream of the last consumer on the loop controls the network. Flow rate and temperature are monitored at various locations in the system.

Strainers are provided to protect the burners from particulate matter, such as pipe scale and coke. Heaters are employed in the system when the temperature of the fuel oil must be increased to meet minimum temperature and/or maximum viscosity requirements of the consumers.

An accumulator is used to maintain system pressure during automatic startup of a spare pump. The accumulator is pressurized by an external nitrogen source and is located in the system to protect critical consumers.

For typical heavy fuel oils stored at temperatures under 200°F (93°C), heaters are used to raise the temperature of the fuel oil in excess of 250°F (121°C) to achieve the proper viscosity at the burners. The designer must consider potential problems during periods of low fuel demands with this system. During these periods, the hot recycle stream makes up a greater proportion of total pump flow that has resulted in cavitation problems at several affiliate locations. In addition, sending the recycle stream back to the atmospheric storage tank poses the risk of hydrocarbon/water boil-over of the tank by exceeding its maximum operating temperature. Solutions to this problem are generally a compromise between risk and operating flexibility.

Heavy resid fuels are typically run off the unit as illustrated in [Figure 6](#). Only a nominal holdup volume is provided in the pressurized surge drum.

DESCRIPTION OF A FUEL GAS SYSTEM

• Refinery Fuel Gas (High Btu/Joule Gas)

A fuel gas system may collect and distribute gas at one or more pressure levels, depending on consumer requirements. A high-pressure system is normally used to supply fuel to gas turbines. The low-pressure system supplies fuel to process furnaces and to offsite consumers such as boilers and incinerators.

The fuel gas system is operated under pressure control. The high-pressure system is controlled by letdown of excess gas to the low-pressure system (upstream of collection drum) or by introducing backup gas (i.e., from an independent process or natural gas source). The low-pressure system is controlled by venting to the flare during periods of excessively high system pressure or by introducing backup gas from the high pressure fuel gas system or other sources; e.g., natural gas, LPG vaporizer, etc. Instruments are provided to monitor flow rates at various locations in the system.

The refinery boilers normally handle large fluctuations in the overall refinery fuel oil/fuel gas balances. They are usually designed for multiple fuel firing and will be set to fire fuel gas preferentially to avoid flaring during sustained high fuel gas production. In some designs, automatic boiler fuel gas firing controls help to maintain a constant fuel gas system pressure. Before this type of control can be specified, a detailed analysis of the fuel and steam balances must be performed to determine if such a design is compatible with both the fuel and steam systems.

A piping network collects and distributes the gas. Sufficient valves and blinds are provided to allow system components, individual consumers or groups of consumers to be isolated for maintenance. All fuel streams are sent to a central collection drum to dampen the effect of wide fluctuations in stream composition and thermal content. The drum is the pressure control point for the system. It provides volume to reduce pressure fluctuations and to disengage entrained liquid.

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The vaporizer is used to dispose of excess or off-specification LPG and as a backup source of fuel gas. Sometimes the functions of the central collection drum and the vaporizer may be incorporated into a single vessel although this is normally not the case. A heater superheats the fuel gas to minimize condensation in the distribution network.

Knockout drums, located immediately upstream of all consumers, disengage and collect any entrained liquid before gas enters the burners. Refer to GP 03-04-01 for design details.

- **Low Btu/Joule Gas**

Low Btu Gas (LBG)/Low Joule Gas (LJG) is produced via an air blown gasification process. This type of gas typically has a heating value in the range of 100-150 Btu/SCF (3,700-5,600 J/Nm³). LBG/LJG from a FLEXICOKING Unit has a heating value of about 100-130 Btu/SCF (3,700-4,800 kJ/Nm³) and is available at low pressures in very large quantities resulting in large diameter piping in the distribution system. Normally, a limited number of the larger onsites furnaces and the offsites boilers are provided with the capability to combust the LBG/LJG. LBG/LJG is consumed in dedicated burners separate from those used for normal refinery fuel gas. Pressure controller(s) and valves are used to modulate LBG/LJG to consumers or the vent/flare system during periods of excessively high system pressure.

Once the FLEXICOKING Unit is started up, the amount of LBG/LJG produced is primarily a function of the amount of coke gasified. Since LBG/LJG is a single source gas, reliability is dependent upon the operation of the FLEXICOKING Unit. Two major short term problems that will quickly affect the availability of LBG/LJG are the loss of the air blower or a problem with the desulfurization unit (if provided). Typically, offsites boilers and some process furnaces designed to fire LBG/LJG utilize auxiliary fuel to provide minimum firing requirements with the capability to meet full load upon total loss of LBG/LJG. The minimum rate for this auxiliary fuel will be a function of burner(s) turndown capability. For fuel gas, minimum firing could be as low as 10% whereas heavy fuel oil may require as much as 25%.

- **Intermediate Btu/Joule Gas**

Intermediate Btu Gas (IBG)/Intermediate Joule Gas (IJG) is produced via an oxygen blown gasification process. This type of gas typically has a heating value in the range of 200-400 Btu/SCF (7,500-15,000 kJ/Nm³).

The gasifier(s) work under high pressure, thus making the fuel suitable for gas turbines (i.e. no need for a fuel gas compressor). Cleanup facilities downstream of the gasifier(s) remove sulfur and other contaminants from the fuel prior to use in the gas turbine(s).

Feed to the gasifier(s) can be coal, petroleum coke or so called petroleum bottoms. Industry interest in the implementation of Integrated Gasification Combined Cycle (IGCC) projects has been growing. This process gasifies low value fuels (such as coal or petroleum coke) for use in efficient power generation cycles.

A simplified scheme showing the IGCC process is shown in [Figure 3B](#).

Refer to [Table 2](#) for heating values and compositions of typical fuel gases.

DESCRIPTION OF A PILOT GAS SYSTEM

Reliable pilot gas is normally supplied from a totally independent source that is separate from the refinery fuel gas system (i.e., from dedicated process units or from an outside source such as natural gas). If such a source is not available, pilot gas may be taken directly from the normal refinery fuel gas system if the instrumentation is as specified in GP 15-01-01 (for pilots with unreliable pilot gas).

For a separate pilot gas system, control is similar to that of a low pressure fuel gas system. Pilot Gas Knockout drums are used to ensure that liquid does not enter the pilot burners.

DESCRIPTION OF A GAS TURBINE FUEL SYSTEM

Gas turbines are capable of firing a wide variety of fuels ranging from natural gas to crude oil. Experience has clearly shown that the cleaner the fuel, the better and more reliable the operation will be.

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Fuel Gas Systems

The gas turbine package typically includes fuel shutoff valves and the fuel control and injection systems. The gas supply system has to be capable of providing clean fuel at constant pressure and with relatively constant heating value.

- High Btu/Joule Gas may be available at the desired pressure (e.g. Natural Gas or high pressure process gas) or some booster compression may be necessary. In any case, the reliability of the source supply and/or compression facilities will have a direct impact on gas turbine availability.
- Fluctuations in the fuel gas Wobbe Index as an indicator of heating value should be kept at a minimum (typically $\pm 5\%$ is acceptable for streams supplying gas turbine fuel). Gas turbine fuel is controlled on a volumetric basis and performance problems can occur when the Wobbe Index fluctuates widely. The gas turbine manufacturer will provide specific guidelines on acceptable Wobbe Index fluctuations.
- Wider Wobbe Index fluctuations may require fuel gas blending facilities or separate fuel gas manifolds and associated modification to the combustor nozzles. Use of special controls (such as fuel gas analyzers) need to be checked for time delay (response times) to be compatible with the precise speed control requirements for industrial gas turbines. Consult with the gas turbine manufacturer or EMRE machinery specialist to determine suitability of such instrumentation.
- Low Btu/Joule Gas is typically available (from process) at low pressure and requires compression. Gas turbine application with such a fuel has been limited in the past but may find wider application in the future. The volumetric fuel flow for LBG/LJG is higher than for HBG/HJG and will affect the air / fuel ratio at the gas turbine. The system, therefore, also has to address the design of the air compression side of the gas turbine in order provide the proper air / fuel ratio. The optimum configuration will depend on specific plant requirements (e.g. possible utilization of bleed air) and the gas turbine manufacturer's capability. Expected compositions of the LBG/LJG should be provided to the gas turbine manufacturer early in the project.
- Intermediate Btu/Joule gas produced by the oxygen blown process will have sufficient pressure for direct feed to the gas turbine. Volumetric flow of the gas may still exceed standard gas turbine limits thus requiring the manufacturer to modify the typical gas turbine design.
- Fuel specification requirements may also dictate the use of fuel gas scrubbing facilities to limit metals, sulfur and particulates from entering the gas turbine combustor.
- Hydrogen content in the fuel can also impact system design. Typically, if the hydrogen content is less than 5% by volume, no special precautions are necessary. For higher values, the manufacturer may require an alternate starting fuel as well as design modifications and additional safety devices specific to hydrogen use. Potential swings in hydrogen content in the fuel gas can also impact the design of the combustion controls.
- Fuel gas streams containing olefins should be avoided if possible, especially when specifying gas turbines with Dry Low NO_x combustors. Olefins may polymerize and form deposits in small diameter orifices. If fuel gas with olefins must be used, generally the manufacturer can modify the design to accommodate the olefins provided the concentration is stable. EMRE's machinery specialists and gas turbine manufacturers should be consulted when considering olefinic fuels. Olefinic fuels can also be problematical when used as a supplementary fuel in a Heat Recovery Steam Generator (HRSG) duct burner. This type of fuel has been known to cause coking/polymerization in the runners of the duct burner.
- Liquid and solids carry over in gaseous fuel systems should be avoided to prevent flashback in the combustion zone. This has been a problem in designs that use dry low NO_x combustors. To combat this problem, recent designs have taken the following steps:
 - Use clean high pressure FG for the gas turbines.
 - Have NG supplier install KO drum(s) to avoid slugs of liquids from contacting downstream facilities.
 - Install coalescer/filter elements downstream of KO drums to eliminate liquid/solids carry-over. These units can be designed to remove 100% of all liquid particles above 3 microns and 99.98% of all particles less than 3 microns.
 - Install NG superheater to assure that the gas entering the gas turbine contains at least 50°F (28 C) superheat.
 - Provide low point drains in all FG piping to avoid accumulation of liquids.
 - Heat trace piping as appropriate to prevent FG condensation.
 - Install SS piping and valving downstream of the filters/separators to prevent solids (rust) carry-over into the combustor system.

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Liquid Fuel Systems

Liquid fuels ranging from distillates to crude oils have been used successfully. High gas turbine service factor can only be maintained if special attention has been paid to all parts of the liquid supply system. The fuel must meet the manufacturer's specification (e.g. water, metals and solids contents) and be delivered to the gas turbine fuel skid at the proper pressure and viscosity.

- Dual fuel storage tanks are recommended to allow filling and settling of one tank while the other is in service. Tank bottom design should be compatible with effective water draw-off.
- Floating suction or high suction nozzles should be used to assure water and solid free fuel.
- Lighter fuels may only require filtration whereas heavier fuels (crude oils and resid fuels) are likely to require other treatment to meet fuel specifications and emissions standards.
- Lighter fuels such as kerosene, naphtha, and NG liquids are directionally better fuels than normal distillate fuel. However, these lighter fuels exhibit low lubricity and low flash points. Both of these characteristics are likely to require special design features and/or special additives to assure fuel supply reliability and safety.
- Soluble salts can be removed from heavily contaminated fuels by water washing. The wash water is then separated from the fuel by centrifuges or electrostatic means.
- Inhibitor systems can be used to inject chemicals into the liquid fuel to avoid high temperature corrosion due to the presence of sodium, vanadium and lead in conjunction with sulfur in the fuel.
- Requires a source of atomizing air (or steam) unless the gas turbine manufacturer fuel skid provides sufficient pressure for mechanical atomization.
- Ash-bearing fuels have not proven to be economically or technically feasible in advanced gas turbines because of firing temperature limitations (resulting in poor fuel economy) and ash deposition on critical film cooling systems in the gas turbine. Refer to EMRE's machinery engineering specialists before considering these applications.

Dual Fuel Systems

- The typical dual fuel system includes NG and distillate fuel with automatic transfer.
- The liquid fuel system has to be in ready mode for automatic switchover during loss of gaseous fuel supply. Ready mode may include running of liquid fuel pump(s) and recirculation of the liquid fuel.
- Automatic switchover to liquid fuel is not always successful. Designer should ensure that the gas turbine and associated equipment will safely shut down on the failure of the auto-transfer.

SYSTEM DESIGN CONSIDERATIONS

RELIABILITY/FLEXIBILITY

The fuel system is an important utility and its reliability and flexibility is essential to successful plant operation. The typical system normally must be able to run continuously, so that it can always provide fuel to critical consumers. The fuel system must be designed to meet the constraints set by the site overall Utility Reliability Philosophy. See Appendix A for a check list of items to review to achieve a reliable system.

The fuel system must include **sufficient flexibility to cover present and likely near-term future operating requirements**. The type of flexibility features provided in a system may include the following:

- Valves and blind flanges to permit future fuel sources or consumers to be tied into the system without a system shutdown, or to permit adding additional system components.
- Integrating the new system with existing fuel systems.
- Sizing the system for the viscosity and temperature requirements of the future fuel.
- A 10% Reserve Capacity Factor (RCF) on total grassroots fuel gas system capacity for future expansion and sudden load swings if Owner approves.

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ENVIRONMENTAL REQUIREMENTS

The fuel system designer should be aware of air pollution criteria, since these may impose limitations on firing certain fuels. The principal criterion is normally the allowable total release of sulfur, expressed as SO₂, per unit of time.

The various plant operating conditions should be evaluated to determine the amount of SO₂ released to the atmosphere. This information forms the basis for furnace stack design as it relates to ground level pollution. Results of this study may indicate that special features, as discussed below, should be included in the fuel system to limit the amount of sulfur released during certain operating conditions.

In process plants that have fuel gas sweetening units, the major source of sulfur is in the liquid fuels. These fuels are normally atmospheric pipestill bottoms, vacuum pipestill bottoms, or heavy fuel oil blends. Therefore, during maximum liquid fuel firing, it may be necessary to reduce the sulfur content of the liquid fuel by blending the normal fuel oil with a low-sulfur stock. Alternatively, naphtha or low-sulfur gas oil could be burned in certain furnaces to meet SO₂ release limitations.

Also, it may be necessary to limit the sulfur content in the liquid fuel when process units release large quantities of sulfur to the atmosphere. This could occur when a sulfur plant is out of service and sour gas from the desulfurization units is disposed of in a flare or furnace, or, in the case of LBG/LJG, in a vent stack.

Limitations on NO_x emissions have also become more stringent especially with the increased employment of gas turbines/waste heat boilers. Designers should consider (and based on local regulations may be required to use) low NO_x technologies for gas turbines, boiler, and process furnaces. If the required NO_x reduction cannot be met with modifications to the combustion equipment, additional measures can be used to lower the NO_x levels in the exhaust including selective catalytic reduction (SCR) and other methods. See [DP XI-N](#) "Reciprocating Engines and Gas Turbines," [DP VIII-F](#) "Burners," and [DP XVIII](#) "Air Pollution Control, Industrial Hygiene, and Noise Control" for more guidance on choosing low NO_x technologies.

To implement these low NO_x technologies additional fuel conditioning equipment may be required. Fuel composition is critical to the design of these low NO_x systems due to the potential of fouling the small orifices used in many of the designs. Olefinic fuel gas streams in particular may require strainers and/or coalescers upstream of low NO_x burners as well as special designs for the burners. The strainer mesh size should be designed such that it will plug prior to the orifices in the downstream equipment (normally 25% or less of the size of the orifice to be protected). Stainless steel piping should also be considered between the strainer and the equipment to be protected due to the potential for pipe scale to plug the orifices. The EMRE fired heater specialists and equipment manufacturers should be consulted for further assistance in fuel system design issues related to low NO_x technologies.

Excess LBG/LJG is flared for pressure control under conditions of excessively high system pressure. However, in certain locations, venting through a stack may be permissible. In these cases, the vent stack must be sized to assure acceptable ground level concentrations.

In locations with stringent air pollution abatement requirements and where there is insufficient sweet gas to blend off with sour fuel gas, it may be necessary to burn sour fuel gas only in those furnaces that have stacks tall enough to assure acceptable ground level concentrations. Depending on local regulations, SO_x removal technologies may also be required.

Continuous flaring should generally be avoided. However, it may be considered if process fuel gas production exceeds plant fuel gas demand and if flaring is environmentally acceptable. Fluctuations in fuel gas availability are typically handled by the combustion control system(s) of boilers (or large furnaces). Fuel gas rates are automatically increased or decreased with a corresponding change in fuel oil rates to maintain steam production or furnace duties.

FUEL SELECTION

The selection of gas and/or liquid hydrocarbons to be used for plant fuel is usually made during the planning stage of a project.

Some factors that influence fuel selection are:

- Gas Containment
- Economics
- Marketing constraints (e.g. inability to sell high sulfur pitch)

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- Air pollution criteria
- Compatibility with existing plant fuel systems
- Process unit requirements (e.g. H₂ plant reformer furnace must burn gas)
- Equipment limitations (e.g. gas turbines, typically require high pressure gas or clean distillate fuel)

FUEL REQUIREMENTS

Design fuel requirements are usually obtained directly from the appropriate process and utility design specifications, as qualified below:

- **Boilers** - Use installed capacity plus over-firing requirements.
- **Heat Recovery Steam Generator (HRSG)** - Use maximum supplementary fuel rate to produce design steam output with minimum waste heat input. (Use cold air operation if HRSG needs to remain on-line when associated gas turbine trips.)
- **Process Fired Heaters** - Use the heat fired; check with the designers for special operating conditions affecting fuel requirements.

The above requirements are usually expressed in Btu/h (kJ/h). They are later translated to fuel requirements on the basis of lower heating values (LHV) for the fuels involved.

FUEL BALANCES

Fuel balances similar to those shown in [Table 1](#) are prepared after the overall fuel production and requirements are defined. The purpose of these balances is to insure that some type of fuel is available under all operating conditions. If fuel oil and fuel gas are used in the same system, they should be expressed on an energy-equivalent basis such as fuel oil equivalent barrels or other consistent units. In developing the balances, the designer must make sure that the cases selected are the limiting ones that will control system sizing. The cases to be investigated may include, but not be limited to, the following:

- Normal plant operation
- Minimum and maximum plant operation
- Minimum and maximum LPG operation (production and/or sales)
- Emergency operations (loss of major producers or consumers - especially FLEXICOKING Unit, Utility failures, etc.), with each emergency operation analyzed separately, as required.
- Seasonality which is especially important for identifying potential gas containment problems.
- Turnaround operation.
- Process variables such as catalyst regeneration, and start and end of run operations on powerformers or hydrofiners.
- Startup

In addition to these cases, the fuel balance must consider the fuel requirements for process use (e.g. Hydrogen Plant feed).

FUEL PROPERTIES

Liquid Fuels - The physical properties of liquid fuels are shown in the GII and heat and material balances for the process units. This information is used for designing the distribution network and sizing equipment.

In the listing of composite liquid fuel characteristics, the metals content (i.e., vanadium, nickel, iron and sodium) must be shown, since these metals have an important bearing on radiant section furnace design.

Cracked stocks should be avoided, as they have been particularly troublesome in causing coking in hot environments and plugging of the fuel nozzles.

Fuel Gas - The heat and material balances for various process units show the composition of gas entering the fuel system from each source. The composition and properties of the mixed fuel gas must be calculated for the various operating cases used in the fuel balance. These data are used for equipment sizing and for determining the extent of the variations in gas composition and thermal content under different operating conditions.

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The hydrocarbon and water dew points of the fuel gas must also be determined. These should be calculated for each individual stream, as well as for the composite stream. This information is used to determine the possible need for superheating and steam tracing of all or part of the fuel gas distribution system, to prevent condensation in the fuel gas lines. Where specific dew point requirements are not specified by fired equipment and gas turbine manufacturers, the dew point should be such that no condensation occurs at the lowest temperature of the distribution system.

Fuel gas systems with high C₄+ content may require superheating, since the hydrocarbon dew point usually falls within the normal operating ranges of low-pressure gas systems. C₄+ rich sections of the distribution system may require heat tracing and insulation.

Low Btu/Low Joule Gas - The properties of the LBG/LJG are shown in the GII and in heat and material balances for the FLEXICOKING Unit. Unless superheating is provided, the LBG/LJG will be water saturated at temperatures in the 95 to 135°F (35 to 57°C) range.

Pilot Gas - The information discussed above is also applicable to pilot gas systems.

FUEL SYSTEM OPERATING CONDITIONS AND CONTROLS

The recommended operating conditions and controls for fuel systems are based on the requirements of typical consumers. Exact consumer requirements should be determined for each system and the operating conditions should be adjusted as required. Operating conditions in existing fuel systems will normally prevail when those systems are expanded.

System control principles are described below. Instrumentation details for individual system components are discussed under "Component Design Considerations".

Fuel Oil

Fuel Oil Systems - The system should deliver fuel oil to the burners at a pressure of 120 to 130 psig (830 to 900 kPa). To ensure good control, an allowance of 50 to 70 psi (345 to 480 kPa) should be provided for the burner control system. Because of turndown requirements and the occasional use of mechanical atomization, burners for boilers may require higher fuel supply pressure than other consumers in the fuel oil system. The designer can satisfy this requirement by providing booster pumps for the boiler fuel, an independent system to service the boilers, or by raising the operating pressure of the entire system. The method selected should be based on considerations of economics, system control, safety and operating requirements.

Fuel oil viscosity should be a maximum of 25 cSt (25 mm²/s) at the burners. However, in some cases, especially when burning resid-type fuels, the ideal burning viscosities may be lower in which case the system should be designed to supply fuel oil at the lower viscosity. Residual and tar type fuel oils (such as vacuum pitch or fuel oils with high ash and metals content) should have a minimum temperature of 350°F (177°C) regardless of the temperature required to meet viscosity requirements. This minimum temperature increases the life of refractory linings and reduces burner maintenance. Proper temperature/viscosity is required to prevent maintenance problems with oil drip-back and to achieve acceptable particulate emissions/opacity.

Heavy fuel oil distribution systems consists of main supply and return headers, plus supply and return laterals to each consumer (see [Figure 1](#)). Recirculation from each consumer is necessary to maintain the minimum temperature and viscosity conditions at the burner under all system flow rates. Fuel oil pumps should have sufficient capacity to recirculate oil at a rate equal to 150% of normal or 125% of maximum requirements (whichever is greater) to each consumer.

The fuel oil system is maintained under pressure control by a PIC located downstream of the last consumer takeoff on the supply header. The controller is set to maintain pressure to the last consumer on the loop under all flow conditions. Recirculated fuel oil should always flow through the pressure control valve to maintain proper system control. The flow of hot oil through this valve at the end of the loop also ensures that there will be no dead legs in the system.

For extremely heavy fuels such as vacuum tower resid, temperatures of the fuel may be controlled back at the unit, and only a surge drum of nominal 30 to 120 minute holdup capacity needs to be provided. Longer storage periods for extremely high temperature fuels >450°F (232°C) may result in cracking of the fuel. A fired or electric heater would be required to maintain the supply temperature of such fuels. A backup liquid fuel to such a system must be selected considering the pressure/temperature of the main fuel, the vaporization tendencies of the cold backup liquid fuel and the possibility of solidification of the fuel mix.