MANUAL

ON

INSTALLATION OF REFINERY INSTRUMENTS AND CONTROL SYSTEMS

PART III—FIRED HEATERS AND INERT GAS GENERATORS

SECOND EDITION
1977

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API RP 550

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FOREWORD

This recommended practice is based on the accumulated knowledge and experience of engineers in the petroleum industry. Its purpose is to aid in the installation of the more generally used measuring, control, and analytical instruments; transmission systems; and related accessories in order to achieve safe, continuous, accurate, and efficient operation with minimum maintenance. Although the information contained herein has been prepared primarily for petroleum refineries, much of it is applicable without change in chemical plants, gasoline plants, and similar installations.

Successful instrumentation depends upon a workable arrangement that incorporates the simplest systems and devices that will satisfy specified requirements. Sufficient schedules, drawings, sketches, and other data should be provided to enable the constructor to install the equipment in the desired manner. The various industry codes and standards, and laws and rulings of regulating bodies should be followed where applicable. The information contained in this publication does not constitute, and should not be construed to be, a code of rules or regulations. Furthermore, it does not grant the right, by implication or otherwise, for manufacture, sale, or use in connection with any method, apparatus, or product covered by letters patent; nor does it ensure anyone against liability for infringement of letters patent.

For maximum plant personnel safety, transmission systems are employed to eliminate the piping of hydrocarbons, acids, and other hazardous or noxious materials to instruments in control rooms. Proper installation is essential in order to utilize the full capabilities which are built into the instrument or transmission system.

In the installation of an instrument, the various components must be accessible for efficient maintenance and certain of these elements must be readable for good operation. Orifices, control valves, transmitters, thermocouples, level gages, and local controllers, as well as analyzer sample points, generally should be readily accessible from grade, permanent platforms, or fixed ladders. In this manual, special consideration is given to the location, accessibility, and readability of the elements.

Users of the various sections of this manual are reminded that in the rapidly advancing field of instrumentation no publication of this type can be complete, nor can any written document be substituted for qualified engineering analysis.

Certain systems are not covered herein because of their very specialized nature and limited use. When one of these systems gains general usage and installation reaches a fair degree of standardization, this section will be revised to incorporate such additional information.

Acknowledgment is made of the work of all the engineers and operating and maintenance personnel who, through years of study, observation, invention, and sometimes trial and error, have contributed to the technology of instrumentation.

Suggested revisions are invited and should be submitted to the director of the Refining Department, American Petroleum Institute, 2101 L Street, N.W., Washington, D.C. 20037.

PREFACE

This section is one of a series which make up RP 550, *Manual on Installation of Refinery Instruments and Control Systems*. RP 550 is composed of four parts:

Part I—Process Instrumentation and Control
Part II—Process Stream Analyzers
Part III—Fired Heaters and Inert Gas Generators
Part IV—Steam Generators

Part I assays the installation of the more commonly used measuring and control instruments, as well as protective devices and related accessories; Part II presents a detailed discussion of process stream analyzers; Part III covers installation requirements for instruments for fired heaters and inert gas generators; and Part IV covers installation requirements for instruments for steam generators. These discussions are supported by detailed information and illustrations to facilitate application of the recommendations.

The format of RP 550, Part I has been changed to facilitate continuity of presentation, convenience of reference, and flexibility of revision. Each section is now being published individually as follows:

Section 1—Flow
Section 2—Level
Section 3—Temperature
Section 4—Pressure
Section 5—Automatic Controllers
Section 6—Control Valves and Accessories
Section 7—Transmission Systems
Section 8—Seals, Purges, and Winterizing
Section 9—Air Supply Systems
Section 10—Hydraulic Systems
Section 11—Electrical Power Supply
Section 12—Control Centers
Section 13—Alarms and Protective Devices

In the preparation of these documents, it was necessary to decide on a logical method of presentation: should each point be explained as fully as possible, or should extensive cross-referencing be done between sections?

The final documents contain a combination of these methods of presentation. An attempt has been made to make each section as complete as possible, with cross-referencing done only where very extensive repetition would have been required.

Users of this recommended practice are cautioned to obtain a complete set of sections in order to efficiently accomplish any cross-referencing that is required for a full understanding of the subject matter.

CONTENTS

SECTION 1—FIRED HEATERS

SECTION 2—INERT GAS GENERATORS

PART III—FIRED HEATERS AND INERT GAS GENERATORS

SECTION 1—FIRED HEATERS

1.1 Scope

This section covers instrumentation for three types of tubular fired heaters:

1. Heaters with natural draft
2. Heaters with forced or induced draft fan(s), or both
3. Heaters with forced and induced draft fans with a combustion air preheater.

These heaters are comprised of heating coils, usually arranged in a refractory setting to provide radiant and convection heating sections. The heaters are usually fired with gas, oil, or a combination of both. The flow of material through the coils is generally countercurrent to the flow of combustion gases in order to achieve good thermal efficiency over a reasonably wide range of heat loads.

1.2 General

Heaters may be divided into two general types, horizontal tube and vertical tube. They may be updraft or downdraft with gas or oil fired burners located in the end or side walls, floor, roof, or any combination thereof.

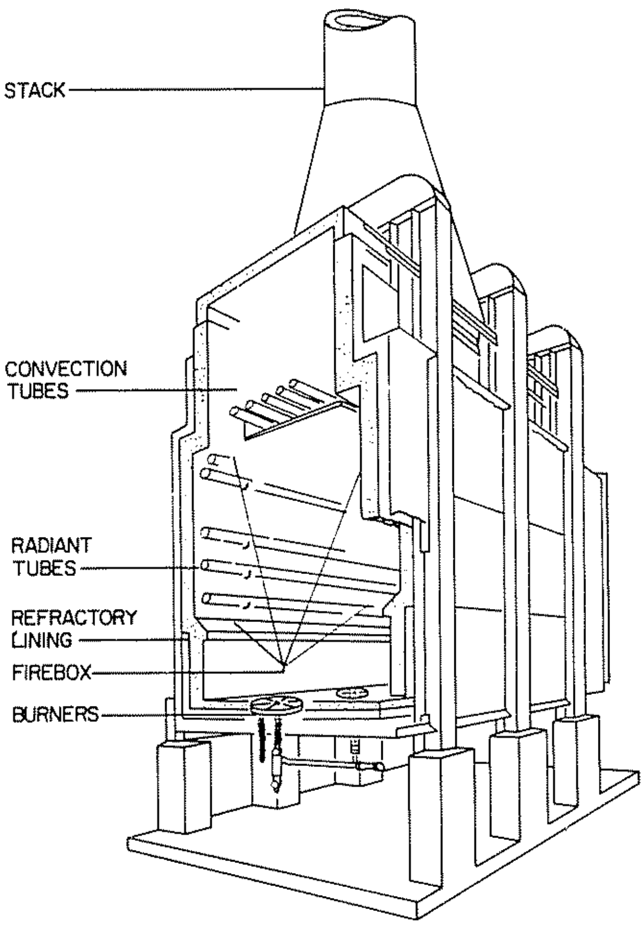


Figure 1-1—Typical Horizontal Tube Heater

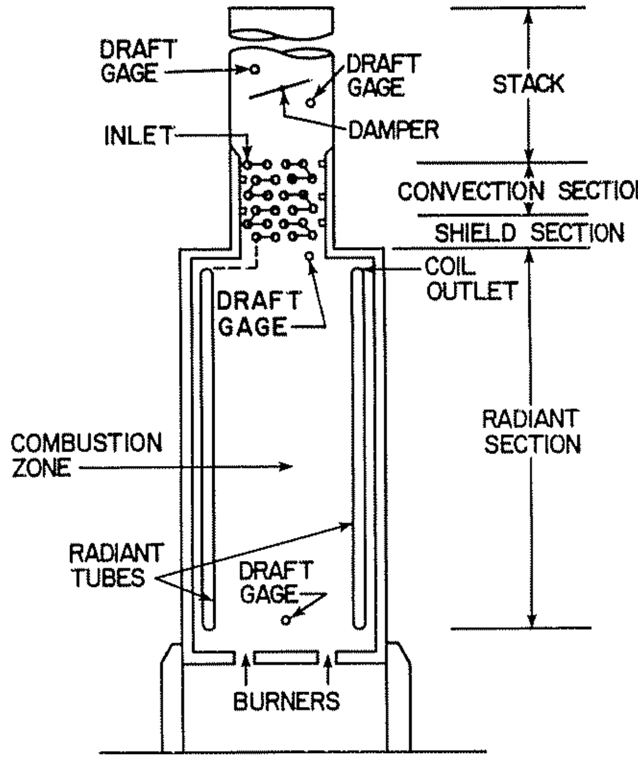


Figure 1-2—Typical Vertical Tube Heater

Fired heaters usually incorporate locations or zones where the primary mode of heat transfer is by radiation and other locations or zones where the primary mode of heat transfer is by convection from combustion gases. The location or zone which is directly exposed to flame radiation is termed the radiant section. The location or zone which does not "see" the flame is termed the convection section. Some areas of fired heaters may incorporate a heating surface where a combination of these heat transfer modes occur.

The sizes and arrangement of tubes in a heater are determined by process requirements (crude oil distillation, cracking, and so forth), the amount of heating surface required, the metal temperature, the allowable flow rate through the tubes, and the pressure drop. A typical horizontal heater is shown in Figure 1-1.

Vertical tube heaters may have either a circular or a rectangular cross section. The burners are usually located in the floor and the radiant tubes are vertical. Figure 1-2 shows a typical vertical heater.

Oil preheating or steam generating tubes are sometimes included in the convection section to improve the heater's operating economy. These auxiliary tubes in a vertical heater may be either vertical or horizontal, depending on the particular design. In horizontal heaters, the auxiliary tubes are usually oriented the same as the other tubes in the convection section.

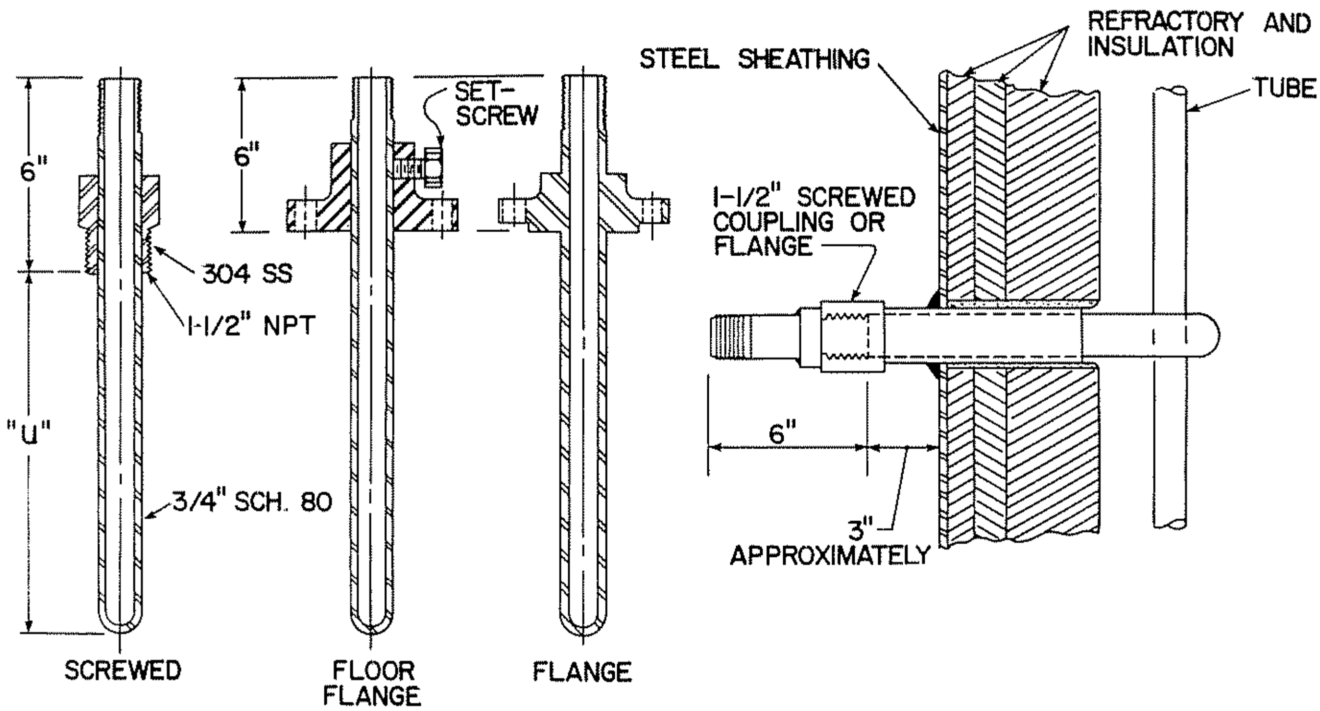
Some installations utilize regenerative or recuperative type combustion air preheaters for flue gas heat recovery

1.3 Measurements

Variables such as temperature, pressure, and flow may be indicated or recorded in order to ensure proper operation of the heater. These variables may also be used to maintain automatic control or to actuate alarms or shutdown devices. Since the purpose of the sensors is to furnish useful information, they should be accessible for reading and for maintenance. Even if a temperature is indicated or recorded in the main control room, local check measurements at the source may be necessary.

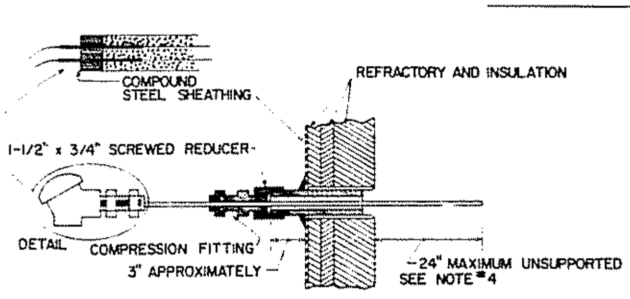
1.4 Temperature

Temperature is usually the most important variable measured on a fired heater. The locations, numbers, and kinds of temperature measuring devices are deter-



Notes:

1. See Table 1-1 for thermowell materials.
2. Material external of the firebox may be other than that specified in Table 1-1.



Notes:

1. The thermocouple should be .500 OD by .120 wall thickness, MgO insulated 14-gage Chromel-Alumel thermocouple wire with AISI Type 446 stainless steel sheath, or material from Table 1-1.
2. The head end of the thermocouple should have 2 inches of exposed wire. The mineral insulation shall be removed to a depth of at least [illegible] inch and potted with compound.
3. The thermocouple head shall have ¾-inch connections.
4. The 24-inch maximium immersion does not apply to top entering installations.

Figure 1-3—Typical Firebox Thermowell Installations

Oil preheating or steam generating tubes are sometimes included in the convection section to improve the heater's operating economy. These auxiliary tubes in a vertical heater may be either vertical or horizontal, depending on the particular design. In horizontal heaters, the auxiliary tubes are usually oriented the same as the other tubes in the convection section.

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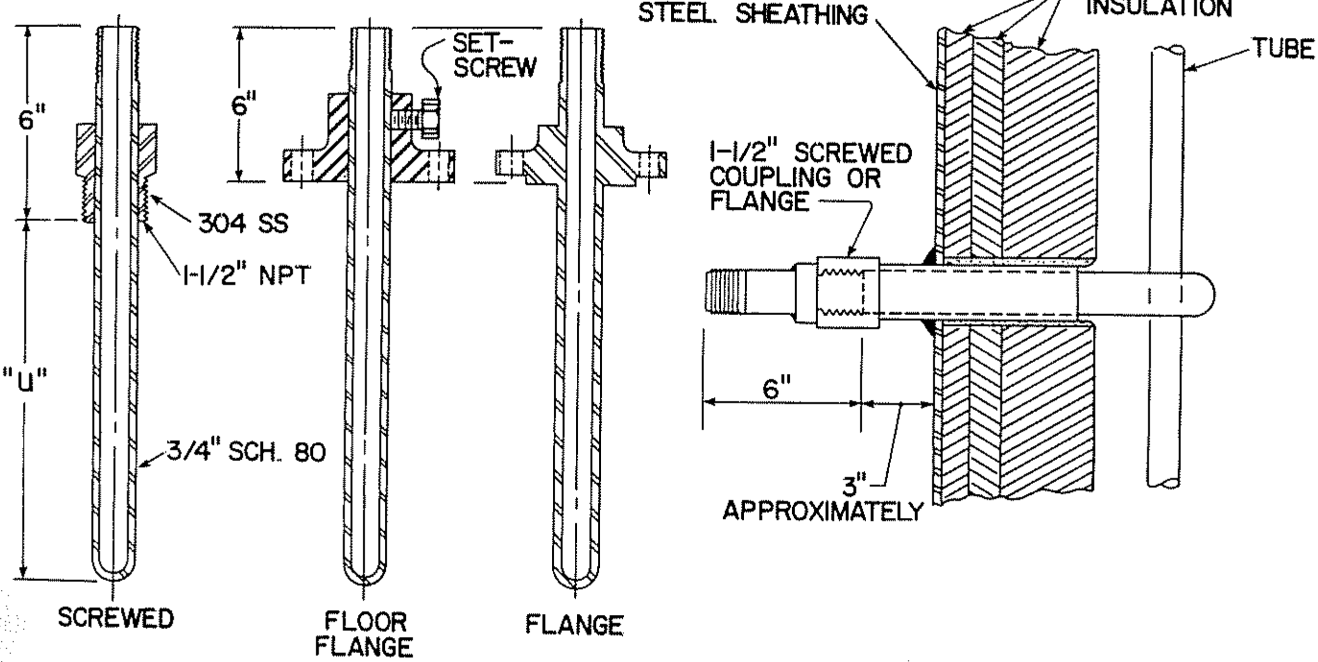

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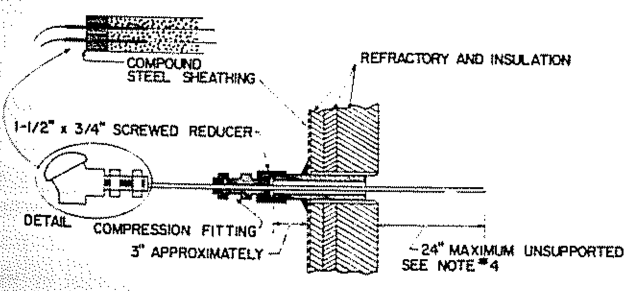

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2. The head end of the thermocouple should have 2 inches of exposed wire. The mineral insulation shall be removed to a depth of at least ¼ inch and potted with compound.
3. The thermocouple head shall have ¾-inch connections.
4. The 24-inch maximium immersion does not apply to top entering installations.

Figure 1-3—Typical Firebox Thermowell Installations mined by the process and the heater design. There should be adequate measurements to (a) evaluate heater performance, (b) establish the proper burner adjustments for efficient operation and a satisfactory stream temperature profile, and (c) permit operation of the heater consistent with selected tube materials.

Temperature is generally measured by thermocouples; however, other primary temperature elements may be used. For a complete discussion of thermocouples, refer to API RP 550, Part I, Section 3—Temperature.

1.4.1 FIREBOX TEMPERATURE

The radiant section temperature measurements may be used as a guide for firing control and to avoid overheating the tubes or the firebox.

These thermocouples should be installed with wells or other protective devices. The point of measurement should not be in a cold draft nor should the burner flame impinge on it. The thermocouple should extend past the shadow of the tube and be placed to avoid dead spots. See Figure 1-3 for typical firebox thermowell installation.

The selection of the type of thermocouple material depends on temperature and atmosphere. An alloy highly resistant to heat, oxidation, and acids and also highly electrically resistant is necessary in the oxidizing atmosphere of firebox service.[1]

Sometimes aspirating-type thermocouples are used to minimize the effect of radiant heat absorption.

Iron-constantan (Type J) thermocouples are not normally used for measuring firebox temperature but may be used within extended temperature limitations if only J-calibration temperature instruments are available. However, the thermocouples should be of sheathed, mineral-insulated or heavy wire, usually 8 gage. Using this procedure will be less costly initially than buying a dual range instrument or a second instrument but has the disadvantage of more frequent thermocouple replacement.

Thermowell materials must be resistant to the firebox temperatures and atmosphere. American Iron and Steel Institute[2] (AISI) Types 446 and 347 are generally acceptable materials. Table 1-1 lists several other materials that have proven satisfactory for thermowells. For some severe services, ceramic or ceramic-coated thermowells have been used. Large diameter (½-inch

[1] For example, Chromel-Alumel (Type K)

[2] American Iron and Steel Institute, 1000 16th Street, N.W., Washington, D.C. 20036

Table 1-1—Thermowell Material For Fired Heater Fireboxes

Maximum Degrees Fahrenheit	*Service or Conditions*	*AISI Type or Tradename*	*Cr*	*Composition[a] Ni*	*Other[b]*
1500	Low sulfur fuel[c]	304	18–20	8–12	
2000	Low sulfur fuel	309	22–24	12–15	
2000	Low sulfur fuel	310	24–26	19–22	
2000	Low sulfur fuel	314	23–26	19–22	1.5–3 Si
2000	Low sulfur fuel	Inconel	14	80	
1500	High sulfur fuel	347	17–19	9–13	Nb–Ta 10xC
2000	High sulfur fuel	Hastelloy X	55–60		15–20 Mo
2000	High sulfur fuel	446[d]	23–27		
2000	High sulfur and high vanadium fuel	Uniloy	50	50	
2500	High sulfur and high vanadium fuel	Kanthal	22		5 Al
2500	High sulfur and high vanadium fuel				Alumina-coated chromium
3000	High sulfur and high vanadium fuel				Molded or cast silica-alumina

[a] Major constituents only. For a complete analysis, refer to the appropriate handbook.
[b] For AISI type stainless steel; consider the balance to be mostly iron.
[c] For purposes of thermowell material selection only, low sulfur fuel is considered to be less than 1.8 percent by weight sulfur.
[d] AISI Type 446 is brittle at 750 to 950 degrees Fahrenheit and at 1100 to 1500 degrees Fahrenheit.

or larger) mineral-insulated thermocouples with the same sheathing material as recommended for thermowells may be used without wells under some conditions. However, if these thermocouples are installed horizontally, additional support may be necessary to prevent sagging.

1.4.2 CONVECTION SECTION TEMPERATURE

Temperature measurement in the convection section is useful for monitoring efficiency and for limiting conditions to within the requirements of the tube and support material. Thermowells must be able to withstand the temperature and atmosphere in the convection section of the heater, although conditions in this section are less severe than those in the radiant section. AISI Type 347 stainless steel is generally a satisfactory thermowell material, but a lower grade alloy may be used since the temperature is lower in the convection section. However, many refineries use the same well material throughout the heater. Aspirating-type thermocouples are sometimes used for this measurement.

1.4.3 STACK TEMPERATURE

The stack temperature measurement is useful in evaluating the overall performance of the heater and in keeping the temperature within the design and material limits of the stack. Too high a temperature may lead to early failure and may also indicate a tube rupture. On the other hand, if the temperature is below the dew point, severe corrosion may result from the presence of acid gases, such as sulfur dioxide and trioxide, in the stack.

A thermocouple with a protection well is usually installed in the flue gas breeching, at or near the connection to the stack, and preferably near the sampling point for the flue gas analysis. Multiple stack heaters should have the temperature measured in each stack. If a common stack is used with several heaters, the temperature should be measured in the breeching of each heater. The thermowell material requirements are essentially the same as they are for the convection section.

In some installations, a reading of average temperatures is required.

1.4.4 CHARGE AND TRANSFER TEMPERATURES

Temperatures of the fluid being heated must be taken at a sufficient number of proper locations to evaluate the heater's performance and ensure satisfactory operation. The location and number of thermocouples depend on the type and service of the heater.

Simple heaters, such as reboilers, may only require outlet and possibly inlet temperatures. Other heaters, such as those used for cracking, high vaporizations, and so forth, should have enough points of measurement to obtain the desired temperature profile. Usually a thermocouple with a protection well is installed in the—

1. Inlet piping to the heater
2. Each crossover from the convection section to the radiant section
3. Each outlet of the heater
4. Outlet piping from the heater.

The temperature of the fluid being heated should be measured wherever the type of heat input changes. In addition, in a heater in which coking might occur, a measurement should be made at least two or three tubes before the outlet. The point can best be selected by considering the expected temperature profile. It is important that the temperature be determined at or near the highest section of the temperature profile.

Thermowells should be located so that they are exposed to the stream and not in a stagnant location or where they might be insulated by coke. They are usually installed so that the bottom of the well faces the flowing charge. This position helps keep the tip clean and ensures better response. Cavitation from flow and the consequent vibration that might lead to fatigue at the resonant frequency of the well are also reduced.

Thermowell material is usually AISI Type 304 stainless steel with a polished surface to avoid fouling. Some materials, such as AISI Type 446, are not satisfactory because of brittleness in certain temperature ranges or because of some types of corrosion.

1.4.5 TUBE SKIN TEMPERATURES

It is advisable to measure tube metal temperatures if heater operating conditions, coking, duty, or temperature may affect tube life. Knowledge of the tube metal temperature is essential for operating within the tube material's limitations (for example, its ability to withstand creep or corrosion). Temperature measurements are used to indicate coking in the tubes. Temperature measuring devices may indicate, record, actuate an alarm, or any combination thereof.

Tube metal temperature measurements are not always accurate. Since these instruments read a point temperature, they do not necessarily measure the maximum tube temperature in the heater. Nevertheless, these temperature measurements are still a valuable operating guide, and therefore an effort should be made to obtain the most accurate measurements possible.

Overall measuring accuracy depends on basic thermocouple accuracy and on the way the thermocouple is attached to the tube. The latter is most important. Bare thermocouples inserted into the tube wall give the most accurate temperature indication but, unfortunately, have too short a service life to be of any value other than to get an initial indication or to check another kind of thermocouple attachment. To achieve a more satisfactory length of service, protection of the thermocouple wire from the corrosive atmosphere of the firebox is essential. One method of protection is a tubular sheath, mineral-insulated thermocouple. Flexibility must be adequate to accommodate furnace tube expansion. The sheath material must resist both corrosion and embrittlement. AISI Type 446 sheath material, ½-inch OD by .120 inch, has been found satisfactory. Other users prefer nickel-based alloys[3], ¼-inch OD by .035-inch wall thickness.

The most common method of installation is by welding a pad-type thermocouple to the surface of the tube. See Figure 1-4. The thermocouple must be in intimate contact wtih the tube. All scale and oxide must be cleaned from the tubes before attaching the thermocouple sheath or block. Grinding is preferred; wire brushing is insufficient. The protected thermocouple attachment must be welded to the tube over its entire contact area. Any gap between the tube and the thermocouple attachment will cause a high reading because the thermocouple will not give up the heat it receives to the tube. Welding the sheath to the tube (either parallel or circumferentially) for 2 inches or more to minimize the effect of conduction along the length of the hot sheath is advisable.

There are several other ways of attaching thermocouples to the tube walls. Whatever design is followed, it is essential to use high-quality workmanship and the best materials.

The tube skin thermocouple may not read the exact tube wall temperature because of errors caused by its installation. For initial checking it may be helpful to peen a temporary thermocouple in the tube close to the permanent installation. Alternatively, optical or radiant heat sensors can be used for this initial check; however, these sensors will indicate scale temperature, temperature of combustion gases, reflected heat from the refractory, or usually a combination of all changes, as well as metal temperature.

[3]For example, Hastelloy X

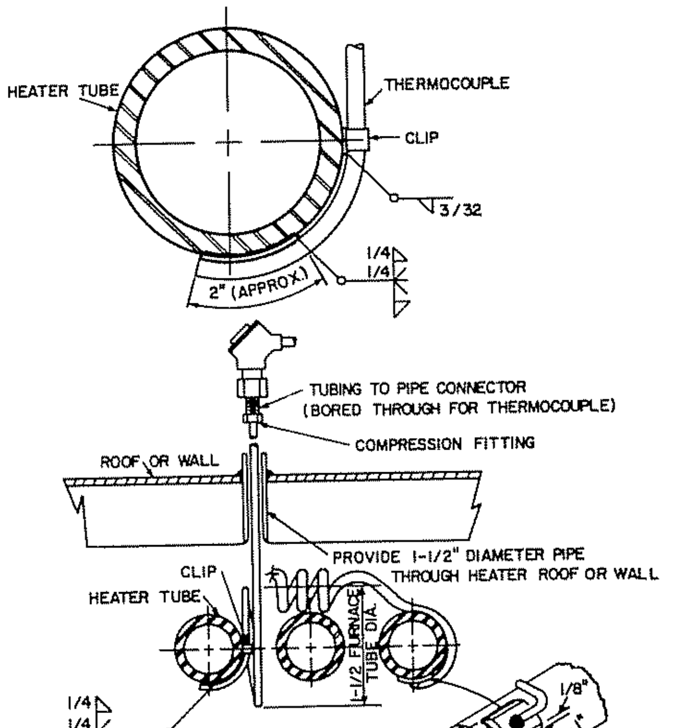


Figure 1-4—Heater Tube Skin Thermocouple Installation

1.4.6 FUEL TEMPERATURE

Fuel gas temperature measurement may be used for corrections to flow measurement to achieve high accuracy. If the measurement is taken downstream of the fuel gas pressure regulator, the presence of hydrocarbon liquids will generally be indicated by a drop in temperature. The resulting signal may be used as an alarm or to increase heat to a fuel gas exchanger.

1.4.7 COMBUSTION AIR PREHEATER TEMPERATURES

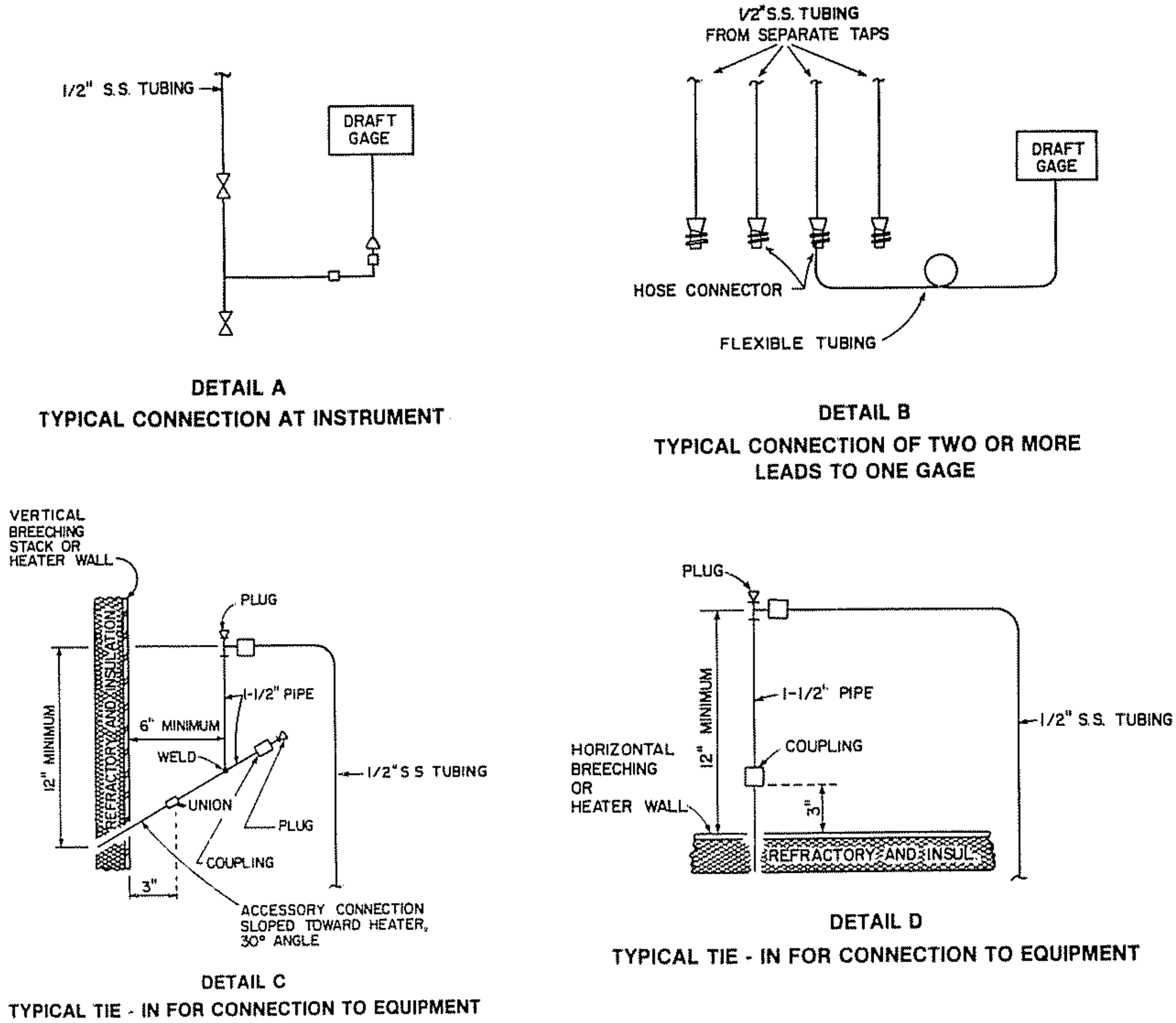
When a combustion air preheater is used, temperature measurements at the air inlet and outlet and the flue gas inlet and outlet are required.

These measurements are useful in evaluating preheater performance and as a guide in maintaining the flue gas and/or air temperature above the dew point to prevent cold end corrosion.

1.5 Pressure and Flow

1.5.1 DRAFT

Draft is an important measurement on any fired equipment. This measurement is used as a guide to proper combustion of the fuel. Pressure (draft) measurements should be made at the outlet of the forced



NOTES:

1. The draft gage should be mounted independently and shall not depend on the piping for support.
2. All pressure lines should be sloped continuously toward the gage, without pockets.
3. Pipe or tubing fittings should be held to a minimum as leakage will adversely affect the draft reading.

Figure 1-5—Draft Gage Installation Details

draft fan, across the air preheater, in the firebox (near the burners and at the top of the radiant section), and across the dampers. See Figure 1-5 which shows typical draft gage installation details. Firebox pressure may be used to roughly control heater air flow on natural draft heaters.

The pressure tap used for control should not be manifolded with other connections.

1.5.2 FUEL FLOW AND PRESSURE MEASUREMENT

Fuel gas pressure and fuel gas and oil flow are measured in various ways. An orifice plate and pressure taps in the main fuel gas line are usually located upstream of all fuel gas controls. Fuel oil pressure must be measured so that proper atomizing steam pressure can be established.

Where fuel gas density varies, flow correction based on changes in density may be desirable.

The type of fuel oil measurement device used depends on the properties of the fuel oil. If viscosity at the flowing temperature is not a problem, a conventional concentric orifice plate may be used. However, fuel oil often is so viscous that it must be heated and circulated past the takeoff branches to the burners. In this case, the rate of flow to the burners may be measured approximately (manually or automatically) by taking the difference between the supply and the return flow. However, the quantity may be determined by tank gages.

Frequently used primary devices for the measurement of viscous fuel oil flow are armored rotameters, quadrant-edged orifices, target meters, and positive displacement meters.

1.5.3 CHARGE FLOW

An orifice plate and flow controller are usually located upstream of the heater coil. If the charge is divided into two or more streams through the heater, the flow in each split is measured, if practical. The flow can be split with manually operated valves if it tends to remain stable. Such systems usually have a high pressure drop, or almost all the charge is vaporized within the heater, or both. If the heated fluid is partially vaporizing in the heater, the system may be unstable and require flow controllers to hold the split constant. Flow controllers on each split are advisable if coking is apt to take place in the lagging stream. If the charge at the inlet is a two-phase flow, it will be necessary to determine the split by some method other than flow measurement. Conventional flow measurement methods may not prove successful. In some cases, pressure readings downstream of flow-splitting valves on each inlet may be of value, as higher pressure could indicate the most flow. However, it must be remembered that higher pressure in some cases may indicate a lower flow due to coking or vaporization.

1.5.4 COMBUSTION AIR FLOW

Air flow is one of the more critical measurements. Air flow is generally relative rather than absolute, and it is often difficult to obtain a reliable signal. Some ways of obtaining this signal are the following:

1. Measurement of the primary element in forced draft duct system for differential pressure transmitter. This measurement would not be operable during alternate natural draft operation. See 1.9.2.8

2. Measurement of differential pressure across the fired heater (combustion air duct to firebox). When soot blowers are installed, the operation of soot blowers will change the differential, thus affecting the combustion control system. Manual control of the firing of the heater is necessary when using soot blowers.

1.6 Analysis

1.6.1 FLUE GAS ANALYSIS

Flue gases are often analyzed for oxygen content and combustibles as a means of monitoring efficiency.

Sampling points should be located at the exit of each combustion chamber and in the exit of the convection section so that the composition of flue gas may be determined by analysis. The exact location of the sampling point is important in obtaining a representative sample.

Where several heaters are in one vicinity, the samples may be manifolded to one analyzer with or without automatic cycle switching.

For additional information on installation of oxygen and flue gas analyzers and sampling systems, refer to API RP 550, Part II, Section 19—Oxygen Analyzers.

1.6.2 BTU MEASUREMENT

In some installations it is desirable to know the heating value of the fuel gas. In general, this measurement would be made on the plant fuel gas system rather than at the individual heater. It may be measured directly or inferentially.

Direct British thermal unit (Btu) measurement may be made with at least two types of continuous calorimeters. In one type, a measured amount of gas is continuously burned with a measured volume of air. The temperature of the combustion products is compared with the air and gas temperature. The air and gas meters are the wet-test type operating in a uniform temperature water bath. A second type consists of an atmospheric pressure constant flow regulator and a bimetal chimney with mechanical linkage to a recorder pen. The regulated flow of gas is burned in the bimetal chimney that has a constant heat loss. The mechanical linkage measures the differential expansion between the chimney elements and positions a pen or pointer. This differential expansion is proportional to the Btu content of the gas.

Perhaps the simplest inferential Btu measurement is direct density measurement of the gas. See API RP 550, Part II, Section 21—Densitometers, for installation of densitometers. The gas density can be correlated to the heating value by laboratory calorimetery or by gas analyses and reference tables. Accurate correlation is difficult if the gas composition varies widely or if a significant amount of inerts are present.

Probably the most sophisticated measuring device is a gas chromatograph with its output fed directly to a computer programmed to calculate the heating value from the total gas analysis. See API RP 550, Part II, Section 15—Gas Chromatographs, for installation of chromatographs.

1.6.3 SMOKE MEASUREMENT

In some locations smoke detectors are required. The equipment monitors smoke density by observing a light beam projected across the flue. These instruments are usually comprised of a light source opposite a bolometer or a photoelectric detector with appropriate readout equipment. As the light source is obscured, higher smoke density is indicated. Provisions must be made to keep the lens of both the light source and detector clean; otherwise, the reading will be too high. Air or steam purging or blanketing over the lenses may be helpful.

1.7 Firing Conditions at the Burners

Stability of the fire conditions is important and is normally detected by visual observation. Instability can be caused by the following:

1. Low oil temperature (This is usually detected by using a thermocouple, filled thermal system, or a resistance bulb and is generally only indicated.)

2. Low fuel pressure (In oil service, the transmitter should be mounted as close as possible to the pressure tap. Consideration should be given to using a narrow range instrument with overrange protection.)

3. Excess air, too high or too low (This can be detected from the oxygen analyzer.)

4. Improper burner adjustments (Poor adjustment can be detected by observation of the flame pattern.)

5. Improper air register settings (Such settings will give an improper flame pattern.)

6. Poor atomization of oil because of wet steam, low steam pressure, low oil temperature, and so forth

7. Dirty or carbonized burners

8. Liquid entrained in fuel gas

9. Water in fuel oil.

1.8 Control Systems

The primary purpose of the control system is to maintain the required heater duty automatically. This is usually done by regulating the fuel flow to the burners in accordance with the temperature at or near the heated fluid outlet. However, in some installations, the controlling variable may be fractionator pressure, bottom level, or some other variable.

During operation, the heater may be subject to disturbances due to variations in charge flow, temperature, and composition. Changes in fuel flow, heating value, and pressure can also introduce disturbances. Various systems of measurement of the upsetting variables and suitable correction of the temperature controller output signal (for an appropriate period of time) can be used.

The control system should correct for these disturbances and stabilize the controlled variable. By doing this, the effects of upsets at various points in the process and control loops are minimized.

1.8.1 FUEL-FLOW/AIR-FLOW CONTROL

On natural draft heaters the fuel/air ratio is maintained through manual adjustment of the burner registers and the stack or inlet damper.

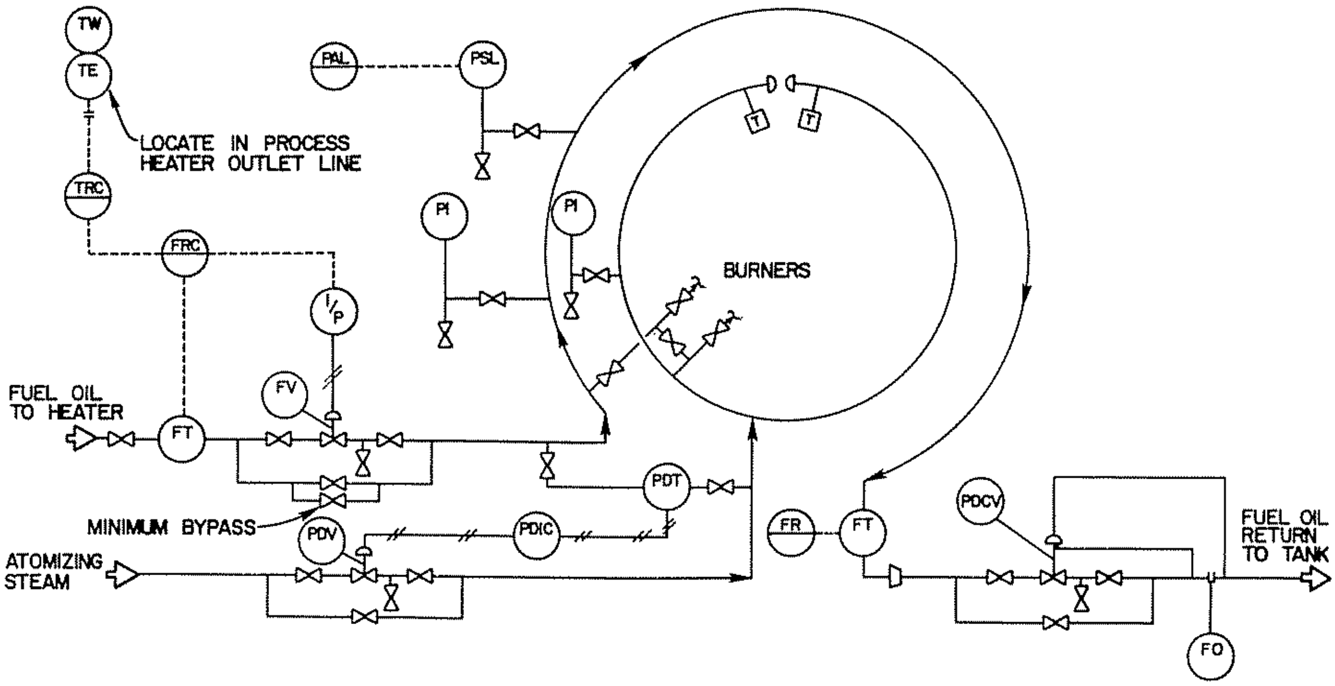
If the correct fuel/air ratio is to be maintained at all times, a suitable combustion guide is essential. The percentage of oxygen in the flue gases is a function of excess air. Sufficient excess air must be maintained at all times to assure complete combustion and safe operating conditions with due allowance for fluctuations in fuel composition. At the same time, the amount of excess air should be limited as it carries heat out of the heater, lowers efficiency, and may affect burner performance. A continuous measurement of the oxygen content of the flue gases provides the most satisfactory guide for adjusting fuel/air ratio, especially when the composition of the fuel may be varying.

The correct fuel/air ratio may be manually set by the operator using the oxygen analyzer-recorder as a guide or automatically controlled by the oxygen analyzer. If automatic control is used, high/low limit relays should be installed. Some users limit the corrective control action to ±5 percent of maximum air flow in the event of analyzer failure.

When plant fuels fluctuate in Btu content, provision should be made for adjusting the fuel-flow/air-flow ratio to compensate for such changes. This may be achieved by adjusting the fuel/air ratio setting to the computing relay shown in Figure 1-6. Operator adjustment of fuel/air ratio is based on changes in oxygen content of stack gases as monitored by the flue-gas analysis.

When the heater has a forced draft fan, the control of the fuel-flow/air-flow ratio can be significantly improved because air flow is readily measured and controlled.

The control method used must be such that the fuel/air ratio can be maintained over the full range of heater



NOTES:

1. For steam tracing, see RP 550, Part I, Section 8.
2. Minimum burner pressure must be high enough to ensure circulation.

Figure 1-9—Typical Heater Fuel Oil System

firing rate demand signal then is transmitted unaltered to the gas valve and the demand for oil calculated by the subtraction unit remains at zero. If the operator desires to fire all oil, he manually reduces the gas demand to zero. The subtraction unit then transmits the firing rate demand signal unaltered to the oil valve since zero is subtracted from it. If the operator desires to fire equal amounts of both fuels, he sets a ratio of 0.5. The output from the station is then 50 percent of the input, and the difference is calculated by the subtraction as the demand signal for oil.

In installations where fuel oil is used for supplemental firing, the fuel oil control valve may be manually loaded, and load swings are controlled by the fuel gas control system.

1.8.5 FIREBOX PRESSURE CONTROL

When the heater has an induced draft fan, the firebox pressure is maintained by automatically adjusting the induced draft control damper by the use of a firebox pressure controller.

The use of an air preheater requires further considerations relating to the control of fuel and combustion air to maintain the heater in a stable operating condition.

Should a preheater or induced draft fan malfunction occur, or should the preheater be taken out of service, the pressure control can be switched, either automatically or manually, to the stack damper.

1.8.6 TYPICAL CONTROL SYSTEMS

Figure 1-6 shows a typical firing control system for a heater equipped with a forced draft fan.

Figure 1-7 shows a typical temperature-pressure cascade system.

Figure 1-8 shows a typical plant fuel oil circulating system.

Figure 1-9 shows a typical heater fuel oil system.

Figure 1-10 shows a typical control system for combination fuel firing for a heater equipped with a forced draft fan.

Figure 1-11 shows a typical combination fuel gas or fuel oil system.

Figure 1-12 shows a typical temperature-flow cascade system.

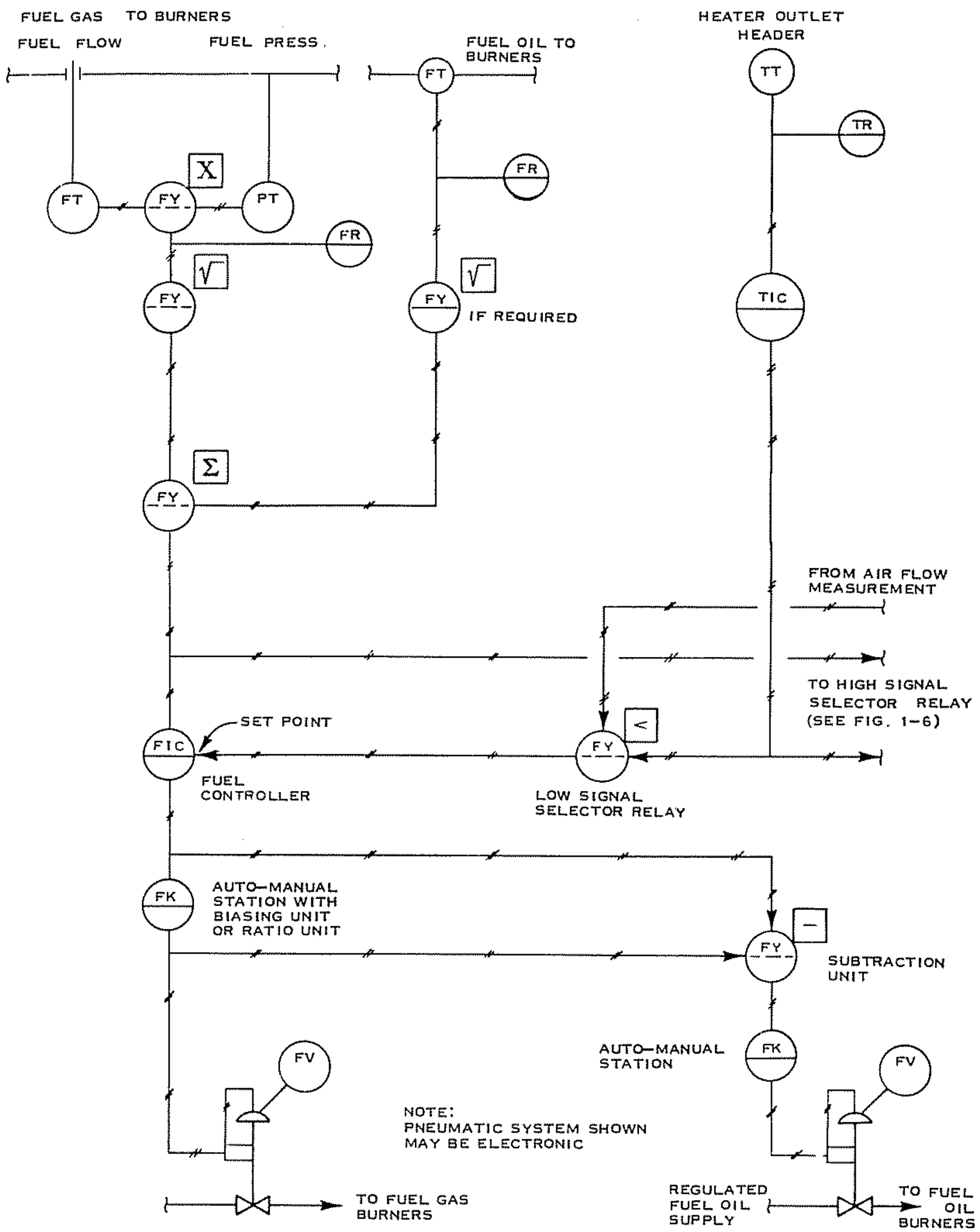
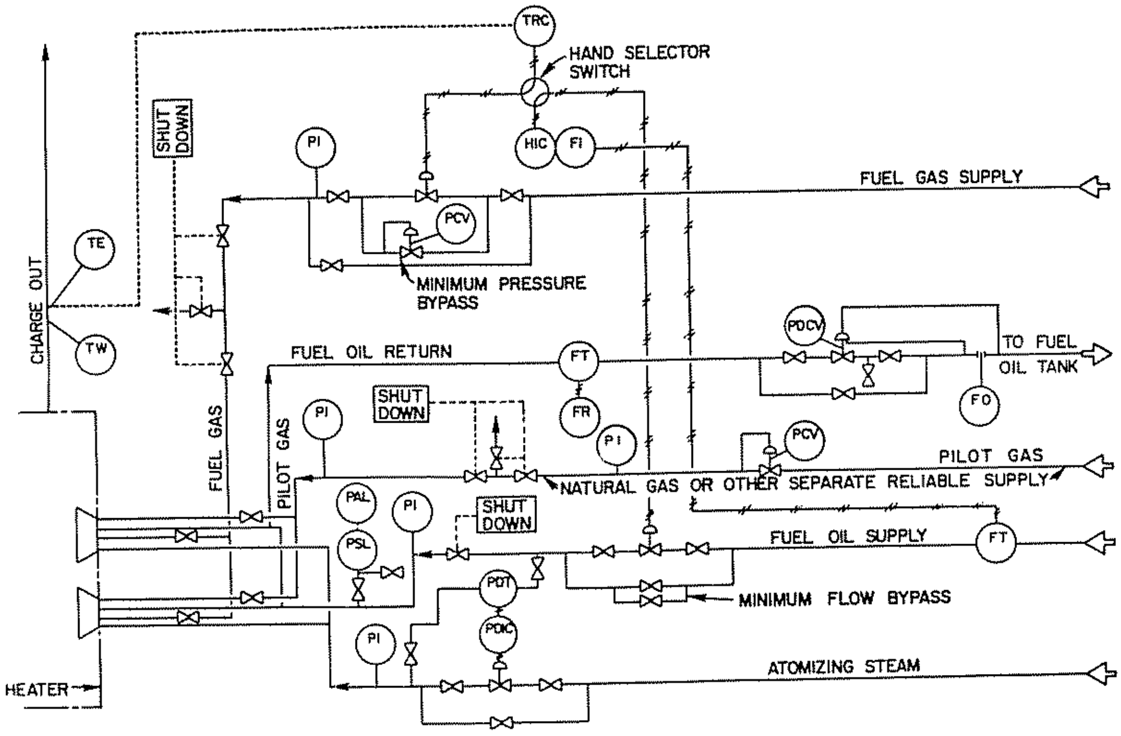


Figure 1-10—Typical Control System for Combination Fuel Firing for a Heater Equipped with a Forced Draft Fan



NOTES:

1. For steam tracing, see RP 550, Part I, Section 8.
2. Minimum burner pressure must be high enough to ensure circulation.

Figure 1-11—Typical Combination Fuel Gas and/or Fuel Oil System

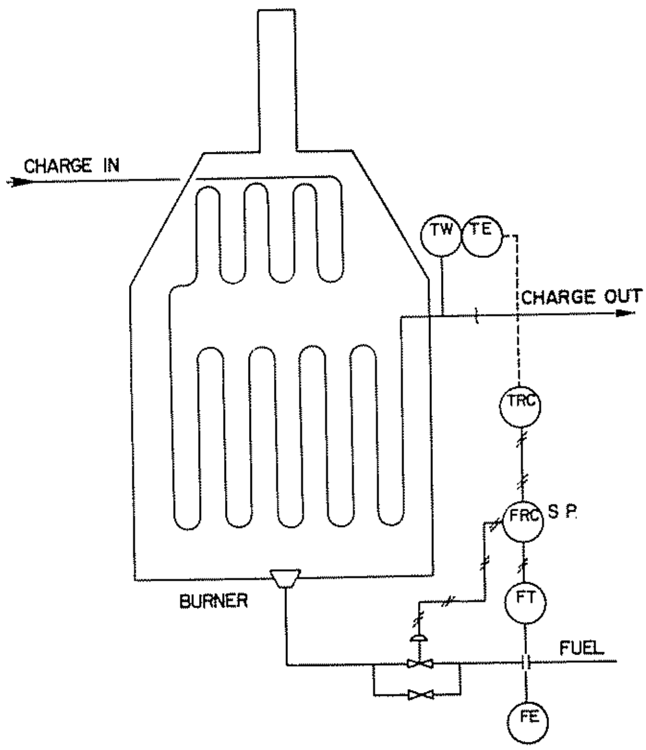


Figure 1-12—Typical Temperature-Flow Cascade System

1.9 Protective Instrumentation

The purpose of protective controls is to ensure safe operating, startup, and shutdown conditions for fired heaters. How elaborate these systems need be depends on several factors including the type of process, the type and size of the heater, what fuels are fired, how reliable the fuel supply is, the type and reliability of the pilots, the operator coverage, and applicable regulations.

A large heater with multiple burners or multiple fuel installations, or both, with a reliable pilot system requires a less elaborate system than a small heater with a less reliable single fuel installation. The greatest danger is from a fuel system that may fail long enough for the flame to die and then reintroduce fuel while the refractory is hot enough to ignite the fuel.

Because of the lack of uniformity in the design and operation of fired heaters, each installation must be studied to determine which failures can lead to trouble.

The final protective control system should be carefully studied to make sure that it cannot itself lead to unsafe conditions, and that it will not make startup unnecessarily difficult or lead to unnecessary shutdowns.

Alarms that are actuated when certain operating conditions approach extreme or unsafe conditions should be installed to caution the operator so that he may take corrective action. In many cases, these conditions can be corrected or equipment can be manually shut down by operating personnel when the alarm is activated. Automatic shutdown is recommended where abnormal conditions can cause a dangerous situation.

Preferably, the primary device that actuates the shutdown should be separate from the one that actuates the preliminary alarm, even though the point of measurement may be identical. As part of the readout of shutdown system status, an annunciating device similar to that used for alarms is recommended. A first failure system is desirable. Most alarm-actuating devices are covered under the respective process variables in the various sections of RP 550, Part I, and the alarms and protective devices are covered in Part I, Section 13—Alarms and Protective Devices.

Foremost consideration should be given to startup conditions in any automatic shutdown system. The automatic shutdown system should allow the heater to start up without undue hindrance from the shutdown devices. If shutdown initiating devices must be temporarily bypassed to start a unit or for testing purposes, visual indication on the central panelboard must be provided. If the user prefers these devices returned to service automatically, this may be accomplished by incorporating a timer in the electrical circuitry or by having the devices themselves incorporate spring loading to return them to service when released by operating personnel

1.9.1 TYPES OF ALARMS

1.9.1.1 Low Fuel Pressure

If fuel pressure falls to a point approaching unstable burner operation, an alarm should be actuated. On gas-fired installations, it is generally desirable to have a pressure switch upstream of the fuel gas pressure regulating valve to detect low pressure in the fuel gas supply. In some installations, it is desirable to have an additional pressure switch downstream of the firing control valve that will detect imminent burner failure.

1.9.1.2 High Fuel Pressure

Overfiring may result from fuel pressure that is too high. In systems where overpressure may be a problem, a pressure switch should be used to alarm personnel to the malfunction. The switch should be located downstream of the fuel firing valve.

1.9.1.3 Low Pilot Gas Pressure

An alarm should be actuated whenever the pilot gas pressure falls too low to maintain a stable pilot flame. Location of the pressure switch downstream of the pilot gas pressure regulator is generally desirable

1.9.1.4 High Stack Temperature

A temperature alarm is frequently used to warn against high stack temperature. This helps detect leaking heater tubes and loss of air preheater drive as well as improper operating conditions.

1.9.1.5 Loss of Flame

In special cases, a flame monitor sensitive only to ultraviolet radiation may be used to actuate an alarm. However, on multiple fuel installations, especially where separate feed supplies are used for pilots, flame monitors are often unnecessary. The pilot fuel supply must be from a reliable source.

1.9.1.6 High Heated-Fluid Temperature

In heaters where the high temperature of the heated fluid may cause or indicate trouble in the process, it may be advisable to have an alarm. Location of the measurement point near the point of maximum temperature is essential. See 1.4.4.

1.9.1.7 High Tube Skin Temperature

An alarm for this condition may be actuated by a thermocouple installed in accordance with 1.4.5 to prevent damage to the tubes by overheating. If the thermocouple separates from the tube, the temperature reading will be high and will cause a false alarm.

1.9.1.8 Low Draft Pressure

In natural draft installations where loss of draft may occur, it is advisable to alarm the conditions unless other suitable means are available to detect the failure. Low draft conditions will cause improper combustion.

1.9.1.9 High Firebox Pressure

An alarm for this variable should be provided to indicate induced draft fan failure, malfunction of dampers, or other cause of high firebox pressure.

1.9.1.10 High Combustibles in the Stack

Improper fuel/air ratio, improper combustion, and leaking heater tubes can each contribute to combustibles in the stack, which can lead to immediate serious problems such as afterburning. It is recommended that a combustibles monitor with an alarm be considered.

1.9.1.11 Low Charge Flow

A low charge flow in the heater tubes may cause overheating which will hasten tube failure. A low-flow alarm should be installed on each pass to the heater.

1.9.1.12 Instrument Air Failure

An alarm should be provided for low instrument air pressure.

1.9.1.13 Loss of Electrical Power (Deenergized Systems)

An alarm should be provided for the loss of instrument electrical power.

1.9.1.14 Low Atomizing Steam Pressure

When liquid fuel is being fired, insufficient atomizing steam pressure can cause instability or loss of flame. An alarm should be provided to warn against this condition.

1.9.1.15 Loss of Air Preheater Drive

Loss of air preheater drive results in decreased fired heater efficiency and may cause mechanical damage to the preheater. An alarm should be provided

1.9.1.16 Low Forced Draft Fan Differential Pressure

The operating forced draft fan differential pressure is often measured and alarmed to indicate the loss of the forced draft fan or malfunction of dampers.

1.9.2 SHUTDOWN DEVICES

Strict attention should be given to the installation of shutdown devices and associated electrical and instrument air supplies to ensure adequate equipment and personnel protection and to minimize nuisance shutdowns. When loss of electrical power or instrument air occurs, it is essential that the process control system, as well as the safety shutdown system, function in a way that has been determined most favorable for overall plant safety. If overall safety is to be accomplished, each component in a control loop must assume a predetermined safe condition. A majority of refinery process plants utilize safety shutdown systems designed to close fuel valves on loss of electrical or instrument air supplies. All shutdown valves must remain in the shutdown position until electrically or manually reset.

1.9.2.1 Low Fuel Pressure

If the fuel pressure decreases below that required for a stable flame, automatic shutdown should occur.

1.9.2.2 Low Pilot Gas Pressure

Where there is concern about the source of pilot gas, a low pilot gas pressure signal may be used to shut down the heater.

1.9.2.3 Loss of Electrical Power

Where electrical safety shutdown devices are installed, a loss of electrical power will automatically shut down the normally energized system. Normally deenergized systems, on the other hand, will not shut down on power failure but will become inoperative during the power outage.

1.9.2.4 Loss of Instrument Air

Loss of instrument air will usually close the firing control valve and interrupt fuel flow when no bypass regulator (as shown in Figure 1-11) has been provided around the valve. In such cases, instrument air failure should close the fuel safety shutoff valve.

1.9.2.5 Loss of Charge Flow

It is advisable to cut back to the minimum firing rate or, under some conditions, provide for automatic shutdown.

1.9.2.6 Loss of Flame

There may be some instances where a reliable source of pilot fuel gas is unavailable; where minimum fire bypass controls are used; or where small, isolated heaters are under infrequent surveillance. Under these or other special conditions, a flame monitor, sensitive only to ultraviolet radiation, may be installed for an automatic shutdown upon loss of flame. Where automatic shutdown on loss of flame is used, dual flame monitors should be considered to avoid nuisance tripping. The system then alarms on loss of flame indication by either of the monitors, and automatic shutdown occurs only when both monitors indicate loss of flame.

1.9.2.7 Loss of Atomizing Steam Pressure

When firing a liquid fuel, loss of atomizing steam may cause loss of flame followed by rapid formation of flammable vapors in the firebox. In such cases, loss of steam pressure may be used to automatically shut down the system.

1.9.2.8 Loss of Combustion Air

In installations with forced draft fans, induced draft fans, air preheaters, or a combination of these, loss of combustion air because of fan failure will require shutdown unless the heater is equipped for alternate operation on natural draft or positive firebox pressure. If natural draft operation is permissible, the transfer may be made by automatically opening the door(s) in the windbox to admit fresh air to the burners. In installations with air preheaters, it is necessary to bypass the preheater. Under these conditions, maintenance of full load may not be possible. When the heater is operating with any fuel under manual control, the manual control setting should not exceed the amount of fuel which can be safely burned under natural draft conditions. See Table 1-2 which suggests alternate actions to be taken with various heater fan/burner combinations.

1.10 Soot Blowers

Soot blowers can be manual or automatic. If automatic, the controls are usually provided by the equipment vendor.

Soot blowers, if required by the quality of the fuel, are normally provided in the convection tube banks of fired heaters to prolong onstream time and maintain thermal efficiency by preventing buildup of soot or other foreign deposits. They may be either rotary or retractable. Consideration should be given before installation to their number and location so that all tubes can be cleaned. Also, the steam pressure used for blowing should be selected so that it is high enough to give sufficient cleaning velocity without causing undue tube erosion. Soot blower operation can be automatically sequenced to reduce operator requirements, to prevent furnace overpressure, to restrict particulate emissions, and to prevent sudden large demands on the steam system.

It may be necessary to manually control the firing of the heater when using the soot blower. See 1.5.4, Item 2.

TABLE 1-2—Alternate Action on Fan or Preheater Failure
(See constraints in Paragraph 1.9.2.8)

Heater Equipped With	*Loss*[a]	*With Natural Draft Burner*	*With Forced Draft Burner*
Forced Draft Fan	FD Fan	Open Door[b] Reduce Firing Open Stack Damper	Shut Down
Induced Draft Fan	ID Fan	Shut Down[c] Open Stack Reduce Firing	—
Forced Draft and Induced Draft Fans	FD Fan	Open Door[b] Reduce Firing Open Stack Damper	Shut Down
	ID Fan	Shut Down Open Stack Reduce Firing	Shut Down
	Both Fans	Shut Down Reduce Firing Open Stack Damper	Shut Down
Forced Draft Fan, Induced Draft Fan, and Preheater	FD Fan	Open Door[b] and Bypass ID Fan and Preheater	Shut Down
	ID Fan and/or Preheater	Bypass ID Fan and Preheater	Bypass ID Fan and Preheater

[a] Reduced firing is recommended in all situations where shutdown is not required.

[b] For natural draft operation (when heater is so equipped); otherwise, shutdown is required. If the dampers fail to open, automatic shutdown after a short time delay is required.

[c] Shutdown is not required if heater has enough natural draft to continue operation.

SECTION 2—INERT GAS GENERATORS

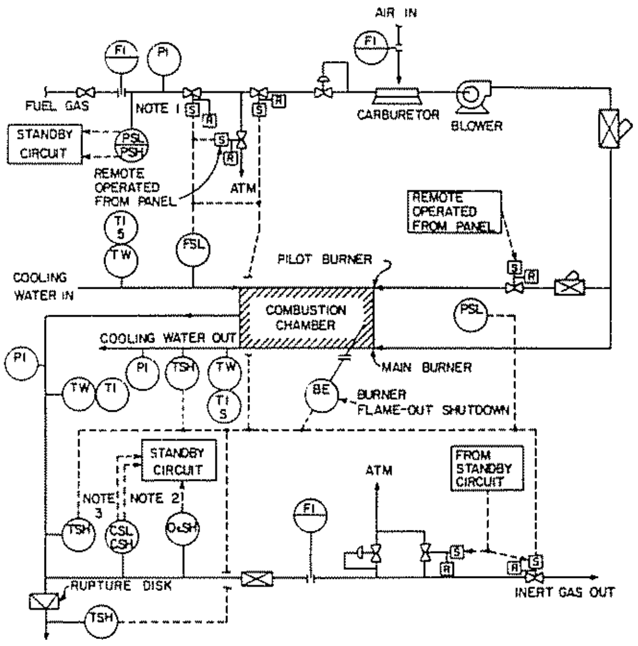
2.1 Scope

This section covers guidelines for the installation of control systems and safety devices for inert gas generators. The instrument and control schemes shown in Figures 2-1 and 2-2 are composites of several of those commonly used.

Inert gas generators produce inert gas by burning a mixture of fuel gas and air. The fuel gas removes most of the oxygen from the air, leaving mainly nitrogen, carbon dioxide, and water. High fuel-to-air ratios result in inert gas containing excess carbon monoxide, whereas low ratios result in excess oxygen.

The product, inert gas, is normally used for tank blanketing, for purging to prevent or reduce explosions, for corrosion control, for chemical reactions, and for processing.

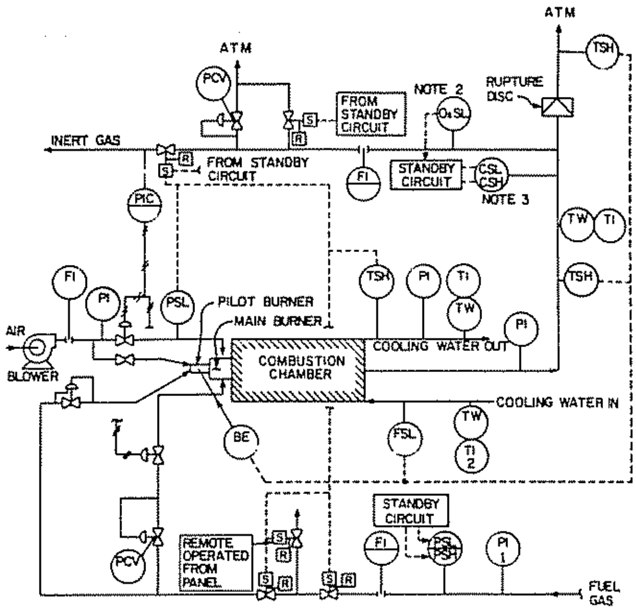
Inert gas generators are usually supplied as a complete packaged unit including all instrumentation, controls, and safety devices. Satisfactory control is established when safety requirements are satisfied and when product quality is obtained under all conditions.



NOTES:

1. High or low pressure puts the generator in a standby state.
2. High oxygen content puts the generator in a standby state.
3. High or low combustibles put the generator in a standby state.

Figure 2-1—Typical Flow Diagram for Premix Inert Gas Generators



NOTES:

1. High or low pressure puts the generator in a standby state.
2. High oxygen content puts the generator in a standby state.
3. High or low combustibles put the generator in a standby state.

Figure 2-2—Typical Flow Diagram for Nozzle-Mix Inert Gas Generators

There are two types of inert gas generators, the premix type and the nozzle-mix type. In premix generators, the mixing of fuel gas and air occurs upstream of the burner, while in nozzle-mix generators, the mixing occurs at the burner. Small units are usually of the premix type since the accurate proportioning of fuel gas and air is difficult at low flow rates. The nozzle-mix type is preferable from a safety viewpoint since it eliminates the transportation of a combustible mixture to the burner nozzle.

Since the inert gas generator's outlet gas is usually too hot for most applications, the gas must be cooled before using. Depending on the product quality needed, two methods of cooling the gas are available: (1) water can be injected directly into the hot gas; or (2) the gas can be indirectly cooled through a heat exchanger. Direct contact cooling has the advantages of providing a generally lower temperature throughout the unit, a longer life, and fewer maintenance problems. However, there is the disadvantage that dissolved oxygen in the water can be introduced into the inert gas. This oxygen usually amounts to approximately 50 to 60 parts per million (ppm) in the gas but can be as high as 5,000 ppm when using surface or other aerated water. When a low oxygen content is required, unless some method is provided to remove the oxygen from the water, the indirect cooling method must be used.

Additional information on inert gas generators may be found in ANSI[4] Standard Z83.2-1971, *Gas Atmosphere Generators*.

2.2 Measurements

Referring to Figures 2-1 and 2-2, the generator control panel should include alarms, running lights, and pushbutton controls, as well as air, fuel, and inert gas flow indicators. Locally mounted temperature indicators should be provided to indicate the temperatures of the effluent gas, the inlet cooling water, and the outlet cooling water.

Locally mounted pressure gages should be provided to indicate fuel gas, air (in the nozzle-mix type only), effluent gas, and cooling water pressure.

2.3 Control Systems

Controls should be provided to maintain the correct fuel-to-air ratio as the load varies. In the premix generator, adjustment of the fuel-to-air ratio is effected mechanically in the carburetor, while the total amount of premixed gas entering the combustion chamber varies with back pressure on the gas blower. In the nozzle-mix generator, one scheme utilizes a pressure controller in the inert gas line that automatically adjusts the amount of fuel and air entering the generator.

A constant fuel gas pressure should be maintained by a pressure regulator to assure uniform inert gas quality.

For larger generators, other control refinements sometimes added for this purpose may include:

1. Automatic changing of the fuel-to-air ratio by an oxygen analyzer controller;

2. Direct measurement and control of the fuel and air for accurate proportioning; and

3. Control of cooling water oxygen content when the direct cooling method is used.

2.3.1 CONTROL UNDER NORMAL OPERATION

Product quality is the major concern in inert gas production. In processes allowing inert gas containing greater than 0.5 percent oxygen, an oxygen analyzer is recommended. Proper type as well as accuracy are important factors since this instrument is usually arranged to place the generator in standby position upon a reading of high oxygen content. In the standby position the generator is operating, but its discharge line is closed, and the inert gas is vented to the atmosphere. The range of the oxygen analyzer should not exceed 0 to 2 percent. Usually, a pressure regulator is placed in the fuel gas line ahead of the carburetor on the premix type of generator and upstream of the safety instrumentation on the nozzle-mix type.

In services requiring inert gas having less than 0.5 percent oxygen, the normal procedure is to use excess fuel, thereby assuring a nonoxidizing atmosphere. In order to ensure that the percentage of combustibles does not get too low and therefore approach an oxidizing condition, a combustibles analyzer is used. The combustibles analyzer is also used to make sure that the percentage of combustibles does not get dangerously high. Again, this analyzer should be of the proper type and accuracy since it is normally arranged to place the generator in standby position when it reaches either too high or too low a combustibles composition. The maximum scale range of the combustibles analyzer should be 0 to 2 percent.

For information on installation of oxygen and combustibles analyzers and sampling systems, refer to RP 550, Part II, Section 19.

2.3.2 MODES OF OPERATION

Inert gas generators are generally operated in two modes, the continuous service mode and the intermittent service mode.

In the continuous service mode, the generator is constantly used in a process. It should have the required instrumentation to automatically respond to demand changes between 35 percent and 100 percent of capacity. Venting of inert gas to maintain stable generator operation may be required below 35 percent of capacity.

In the intermittent service mode the generator is used periodically and is shut down the rest of the time. For example, intermittent service is required for a generator used for purging a reactor prior to regeneration. Since intermittent service normally involves less generator "on" time yet more operator attention when running, not all of the automatic instrumentation indicated for continuous service may be needed. Instead, the generator is made capable of meeting reductions in demand by automatic venting to the atmosphere. Operation down to 35 percent of capacity, however,

[4] American National Standards Institute, 1430 Broadway, New York, N.Y. 10018

should be possible by manual adjustment and without venting to the atmosphere.

2.4 Protective Instrumentation

It is imperative that instrumentation be provided not only to indicate when an unsafe or potentially unsafe condition exists but also to shut down (or bypass) the generator under certain conditions. This is because inert gases are used in many processes requiring absolute assurance that they are truly inert. Here, safety is the overriding concern. Installation of alarms and protective devices is covered in RP 550, Part I, Section 13.

2.4.1 ALARMS

Various alarms and/or shutdown systems are provided to guard against abnormal conditions. The alarm system should indicate the abnormal variable at the control valve. All alarm signals should be of the lock-in type requiring operator acknowledgement prior to extinguishing, even after the alarm conditions have returned to normal. All alarm lights should be of the first-out type to indicate which malfunction initiated the shutdown or standby.

2.4.2 SHUTDOWN DEVICES

The major considerations for safe operation of inert gas generators are flame stability and the immediate detection of flame failure. An explosive mixture is released into the generator vessel soon after flameout. Thus it is extremely important that reliable means be provided for automatically shutting off the fuel and the generator discharge line upon flame failure. A flame detector should be used for this purpose, but its arrangement in the system will differ with burner size and type. An automatic blower motor stop will give added protection.

On a nozzle-mix generator, the flame detector should be arranged to sight the pilot as well as the main burner flames.

On a small premix generator, the main burner should be monitored. However, on a large premix generator, the flame detector is generally arranged to sight the pilot and not the main burner.

The flame detector should be the quick-acting type with a detection period of 1 to 4 seconds. Three types are used: ac flame rectification, infrared, and ultraviolet. The infrared type is not recommended because of precautions that must be taken to avoid sighting hot brickwork that emits considerable infrared light. Using such a detector may prevent a required shutdown after a flameout.

A built-in circuit check is desirable to ensure that flame detectors are operable at all times.

In a typical premix burner, the combustible gas mixture is transported 10 to 15 feet. To prevent backfiring, flame arresters should be used in all lines carrying such mixtures. Backfiring from the main burner may result in a high-velocity shock wave. For this reason, the flame arrester in the main gas line is sometimes equipped with a pressure relief valve, or if this is not sufficiently fast acting, a rupture disc.

All valves in the system should be of the fail-safe type, acting to shut down the unit in case of actuator power supply failure.

An automatic vent valve to the atmosphere on the generator outlet should be provided on all generator installations for use during startup, except in those plants where it is permissible for the air or steam purge to pass through the process equipment. This vent valve may also be used to relieve unsafe generator discharge pressure. In addition, a rupture disc is recommended in case of valve failure.

Depending on the malfunction, the generator should either completely shut down or be placed in a standby state. Automatic shutdown involves closing the generator discharge line, opening the vent, closing the fuel gas line, and purging the generator.

Complete, automatic shutdown should occur in the following cases:

1. Power failure
2. Flame failure
3. Low flow of cooling water or high cooling water temperature
4. Low air pressure
5. Broken rupture disc

Standby operation should occur in the following cases:

1. High or low gas pressure in the combustor, or
2. Substandard inert gas quality.

2.4.3 INTERLOCK DEVICES

Interlock is defined in NFPA[5] Standard 85B, *Pre-*

[5]National Fire Protection Association, 60 Batterymarch Street, Boston, Mass. 02110.

vention of Furnace Explosions in Natural Gas-Fired Multiple Burner-Boiler Furnaces, and is quoted below for ready reference.

> 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 offending or related piece of equipment, or to prevent proceeding in an improper sequence in order to avoid a hazardous condition.

The safety control system for an inert gas generator should be completely interlocked for sequential operation. Any attempt to override this sequence should trigger an alarm and should make further operation impossible until corrective action has been taken.

Interlock systems are provided to prevent all potentially unsafe operating conditions. Interlocks are associated with both a startup procedure and an orderly shutdown sequence.

An interlock can react when a single variable falls outside the preset limits, or it can wait until more than one variable is off limits before action is initiated.

2.5 Programmed Ignition Systems

The main purpose of programmed ignition systems is to minimize hazards during the lighting off of fired inert gas generators. The majority of inert gas generator explosions occurs during this critical period.

Explosions that occur during normal operations are often triggered by an unexpected flameout and caused by human error during hurried attempts to get the inert gas generator back on the line. It is during this kind of burner ignition that the programmed or automatic system is most beneficial.

To purge the ignition system before startup, at least four air volume changes throughout the system are recommended. One change is satisfactory after shutdown. The purge rate should equal or exceed 25 percent of the rated flow.

The method of igniting the burner depends on its type and size:

1. *Nozzle-mix generators*. Burners for these generators normally have an intermittent pilot ignited by an electric arc. In most cases, it is difficult to maintain a continuous pilot at maximum generator output because of high throat velocity. Thus, upon ignition of of the main burner, the pilot is usually shut off.

2. *Small premix generators*. A pilot is normally not required, and the burner is lit directly by an electric arc.

3. *Large premix generators*. A continuous pilot having electric arc ignition is sometimes used.

A pressure regulator is recommended in the fuel gas line ahead of the carburetor in the premix type of generator and ahead of the main burner in the nozzle-mix type.