

MANUAL  
ON  
INSTALLATION OF REFINERY INSTRUMENTS  
AND CONTROL SYSTEMS  
PART IV—STEAM GENERATORS

FIRST EDITION  
1975

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A  
API RP 550

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ON  
INSTALLATION OF REFINERY INSTRUMENTS  
AND CONTROL SYSTEMS

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AMERICAN PETROLEUM INSTITUTE  
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## FOREWORD

This is the fourth part of the manual and represents the latest suggested or generally used practices in the installation of the kinds of devices covered in Parts I and II as they apply to the measurement and control of steam generators.

Part IV covers recommended practices that specifically apply to instrument and control system installations for steam generation facilities in petroleum refinery and other hydrocarbon processing plants. The installation of primary measuring instruments, control systems, alarm and shutdown systems, and automatic startup and shutdown systems are discussed for steam generators, carbon monoxide or waste gas steam generators, gas turbine exhaust fired steam generators, and unfired waste heat steam generators.

Successful instrumentation depends upon a workable arrangement that incorporates the simplest systems and devices that will satisfy specified requirements. Schedules, drawings, sketches, and other data should be provided in sufficient amounts to enable the constructor to install the equipment in the desired manner. The various industry codes and standards and the laws and rulings of regulating bodies should be followed where applicable.

For maximum plant personnel safety, it is recommended that transmission systems be employed to eliminate the piping of hydrocarbons, acids, and other hazardous or noxious materials to the instruments in the control rooms.

The instrument installations should be carefully analyzed for good operation. The various components must be accessible for efficient maintenance, free of vibration, and certain of these elements should be located for convenient readability. Orifices, control valves, transmitters, thermocouples, level gages, and local controllers, as well as analyzer sample points, should, in general, 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.

Proper installation is essential in order to utilize the full capabilities that are built into the instrument systems and to realize the greatest return on the investment. In many instances, the instrument difficulties encountered have been traced to incorrect installation.

This part of the manual has been written as a general guide for designing and installing operable, safe, and efficient instrument and control systems for steam generators in petroleum refineries and related plants. It is intended to be used as a complement to Parts I and II of the manual. As such, it should be useful to design engineers, instrument construction and maintenance personnel, and process operators. It is no substitute for experience and proficiency in these fields, although it will be a help in achieving such experience and proficiency. Because of the lack of uniformity in the design and requirements of these processes, the complete instrumentation and control system must be studied to determine if it will enable the unit to be operated, started up, and shut down satisfactorily and safely.

There are many specific features of these installations that require special attention in order to assure safe and efficient operation of the plant and to ensure that the plant can be started up or shut down with safety to the operating personnel and without damage to the equipment or to the processes that it serves. Special effort

has been made to point out pitfalls in these installations but only a general guide can be established. Those concerned with the general installation will find it necessary to think through the function of each installation for each probable operating condition.

Background information is presented to show the reasons for customary installations. This has necessitated discussion of the processes, instrument application, and instrument design. For this reason, Part IV of the manual is organized with the different processes as the major headings and the types of measurement or control function as subheadings under these processes.

There are enough unique instrumentation and control problems in these systems to require treatment separate from process control on refinery units. In the past, combustion control has developed along a path that has been considerably divergent from the development of process control. Consequently, process operators and instrument mechanics have required special training to handle the steam generator instrumentation that has been integrated with the process unit control centers. Control system design engineers familiar with one kind of plant have usually not felt proficient with the other. Actually, many of the differences are more apparent than real. For this reason, the specific problems, differences, and similarities in the installation of these instruments and control systems are discussed.

The features of instruments and control systems that are covered sufficiently elsewhere in the manual are not covered in this section. Therefore, frequent reference is made to Parts I and II of the manual.

The steam generation facilities must be considered as an integral part of the refinery or process plant. These facilities cannot be considered separately even from the safety shutdown standpoint because a steam supply failure to some processes may be more dangerous to more personnel and equipment than taking a low level risk with the steam generation facilities by not shutting down on certain upsets. The overall view should include all risks due to direct process upsets, shutdown and startup of affected processes, and loss of essential utilities such as fire water, as well as what might happen to the steam generation facilities.

## 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 steam generators. These discussions are supported by detailed information and illustrations to facilitate application of the recommendations.

This manual 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 and control instruments 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 to chemical plants, gasoline plants, and similar installations.

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 and control of steam generators.

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.

Users 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. Furthermore, federal, state, and local regulations should be consulted.

Certain instruments are not covered herein because of their very specialized nature and limited use. When one of these devices (or classes of devices) gains general usage, and when installation reaches a fair degree of standardization, this manual will be revised to incorporate such additional information.

Suggested revisions are invited and should be submitted to the Director of Refining, American Petroleum Institute, 1801 K Street, N.W., Washington, D.C. 20006.

## CONTENTS

### PAGE

### SECTION 1—STEAM GENERATORS

|                                                                                   |    |
|-----------------------------------------------------------------------------------|----|
| 1.1 Scope                                                                         | 1  |
| 1.2 Measurements                                                                  | 1  |
| 1.2.1 Water Level in Steam Drum                                                   | 1  |
| 1.2.2 Steam Pressure                                                              | 1  |
| 1.2.3 Feedwater Pressure                                                          | 2  |
| 1.2.4 Superheated Steam Temperature                                               | 2  |
| 1.2.5 Draft Pressure of Gases and Air Entering or Leaving the<br>Various Sections | 2  |
| 1.2.6 Fuel Pressure                                                               | 3  |
| 1.2.7 Analysis                                                                    | 3  |
| 1.2.8 Feedwater Temperature                                                       | 5  |
| 1.2.9 Flue Gas Temperature                                                        | 5  |
| 1.2.10 Air Temperature                                                            | 6  |
| 1.2.11 Fuel Temperature                                                           | 6  |
| 1.2.12 Fuel Flow                                                                  | 7  |
| 1.2.13 Steam Flow                                                                 | 8  |
| 1.2.14 Feedwater Flow                                                             | 8  |
| 1.2.15 Air Flow                                                                   | 8  |
| 1.2.16 Firing Conditions at the Burners                                           | 8  |
| 1.2.17 Steam Generator Feedwater Quality                                          | 10 |
| 1.3 Control Systems                                                               | 10 |
| 1.3.1 Combustion                                                                  | 10 |
| 1.3.2 Feedwater                                                                   | 18 |
| 1.3.3 Blowdown                                                                    | 18 |
| 1.3.4 Soot Blowers                                                                | 21 |
| 1.4 Protective Instrumentation                                                    | 21 |
| 1.4.1 Annunciators and Alarm Lights                                               | 21 |
| 1.4.2 Safety Shutdown Systems                                                     | 24 |
| 1.4.3 Alarm and Shutdown Devices                                                  | 24 |
| 1.4.4 Interlocks                                                                  | 26 |
| 1.4.5 Testing of Shutdown Devices and Systems                                     | 26 |
| 1.5 Programmed Ignition Systems                                                   | 26 |
| 1.5.1 Design for On-Line Testing                                                  | 26 |
| 1.5.2 Components and Installation                                                 | 27 |
| 1.5.3 Sequence of Operations                                                      | 27 |
| 1.5.4 Flame Detectors                                                             | 29 |
| 1.5.5 Power Supplies                                                              | 29 |

|                                                                    | PAGE |
|--------------------------------------------------------------------|------|
| <b>SECTION 2—CARBON MONOXIDE OR WASTE GAS<br/>STEAM GENERATORS</b> |      |
| 2.1 Scope .....                                                    | 29   |
| 2.2 Measurements .....                                             | 30   |
| 2.3 Control Systems .....                                          | 31   |
| 2.3.1 Combustion .....                                             | 31   |
| 2.3.2 Feedwater .....                                              | 31   |
| 2.3.3 Blowdown .....                                               | 32   |
| 2.3.4 Auxiliary .....                                              | 32   |
| 2.4 Protective Instrumentation .....                               | 35   |
| 2.4.1 Alarms .....                                                 | 35   |
| 2.4.2 Shutdown Devices .....                                       | 35   |
| 2.5 Programmed Ignition Systems .....                              | 35   |
| <b>SECTION 3—GAS TURBINE EXHAUST FIRED STEAM<br/>GENERATORS</b>    |      |
| 3.1 Scope .....                                                    | 37   |
| 3.2 Measurements .....                                             | 37   |
| 3.3 Control Systems .....                                          | 37   |
| 3.3.1 Decoupling Controls .....                                    | 38   |
| 3.3.2 Coupling Controls .....                                      | 39   |
| 3.3.3 Turbine Exhaust Bypass Control .....                         | 39   |
| 3.4 Protective Instrumentation .....                               | 39   |
| 3.4.1 Alarms .....                                                 | 39   |
| 3.4.2 Shutdown Devices .....                                       | 40   |
| <b>SECTION 4—UNFIRED WASTE HEAT STEAM GENERATORS</b>               |      |
| 4.1 Scope .....                                                    | 40   |
| 4.2 Measurements .....                                             | 40   |
| 4.3 Control Systems .....                                          | 40   |
| 4.3.1 Drum Level .....                                             | 40   |
| 4.3.2 Heat Input .....                                             | 40   |
| 4.3.3 Steam Temperature .....                                      | 41   |
| 4.3.4 Pressure .....                                               | 41   |
| 4.3.5 Blowdown .....                                               | 41   |
| 4.4 Protective Instrumentation—Alarms .....                        | 41   |

## PART IV—STEAM GENERATORS

### SECTION 1—STEAM GENERATORS

#### 1.1 Scope

This section covers instrumentation and control systems generally applicable to steam-generating units in petroleum processing plants. Measurements, control systems, protective instrumentation, and programmed burner ignition systems are discussed. This discussion applies to steam-generating units of either the field-erected or shop-fabricated design having a pressurized (forced-draft) type furnace with integral burners. Although such units may be fired with several types of fuel, only the gas and liquid fuels are covered.

#### 1.2 Measurements

Many operating variables on a steam generator must be measured so that it may be operated as required by both external and internal conditions. These measurements may be necessary either for operator guidance, manual control, automatic control, safety alarms, safety shutdown, automatic light-off, accounting, economical load distribution, or any combination of these. The measurements for automatic control and safety devices are predominant and most important. For this reason, the installation of measuring devices that will perform accurately and continuously will be considered before discussing the systems that are actuated by these measurements.

The measurements required on a steam generator will vary with the conditions under which the unit must operate. The growing complexity of steam-generating units and their connected systems is promoting the need for an increased number of measurements and emphasizing the need for careful coordination of these measurements with the overall design and functional objectives of the unit. Special consideration should be given to measurements necessary to meet plant and insurance safety practices along with mandatory measurements required by state, federal, and local codes that apply to the locale in which the equipment is installed.

Most modern measurement and control systems for steam-generation units utilize a central control panel. There is generally a local indication of some measurements that are used for local operation. Many of these local indicators are normally furnished as a part of the basic steam-generator package.

Transmitters should be installed as close as practical to the source of the measurement with consideration being given to excessive vibration, temperature, and

access for periodic maintenance. Suggestions for the location of instrument and control equipment connections can be found in SAMA—ABMA\* "Recommendations for Location of Instrument and Control Connections for the Operation and Control of Watertube Boilers."

#### 1.2.1 WATER LEVEL IN STEAM DRUM

The water level in a steam drum is controlled by regulating the feedwater flow and is normally measured and recorded using a differential pressure type level transmitter or an external cage displacement type level transmitter. Separate indication of the water level is required by the ASME† Boiler and Pressure Vessel Code. This code should be referred to before installing either local or remote level indicators.

Refer to Figure 1-1 for a typical differential pressure type level transmitter installation. It is recommended that the condensate reservoir be added to the top leg above 800 pounds per square inch gage (psig). Density compensation should be considered. Refer to RP 550, Part I, Section 2 for installation of the displacer type level transmitter.

#### 1.2.2 STEAM PRESSURE

##### 1.2.2.1 Header Pressure

Header pressure is required for control and operator guidance and normally recorded on a panel. On multiple steam generators, this is the pressure of the common header for the steam generators. Where it is used for control, some users install dual transmitters, one of which may go to the master gage under normal conditions. Refer to RP 550, Part I, Section 4 for installations.

##### 1.2.2.2 Drum Pressure

Drum pressure is required for operator guidance and is normally indicated but sometimes recorded on the steam-generator panel. This pressure is the operating pressure of the individual steam drum. Refer to RP 550, Part I, Section 4 for installation.

\*As recommended by the Recorder-Controller Section of the Scientific Apparatus Makers Association and the American Boiler Manufacturers Association. Available through Process Measurement and Control Section, SAMA, 370 Lexington Avenue, New York, NY 10017.

†American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

- NOTES:
1. ALL PIPE, TUBING, VALVES, AND FITTINGS SHALL CONFORM WITH ALL APPLICABLE CODES.
  2. LINES TO SLOPE A MINIMUM OF 1" PER FOOT TOWARDS TRANSMITTER.
  3. DISTANCE BETWEEN DRUM CONNECTIONS AND TRANSMITTER SHOULD NOT EXCEED 25 FEET. LINES TO BE RUN TOGETHER WITH SUFFICIENT SUPPORTS TO PREVENT SAGGING. INSULATE AND PROVIDE FREEZE PROTECTION FOR ALL OUTDOOR PIPING.
  5. "X" AND "Y" DIMENSIONS ARE DETERMINED BY DESIGN OF STEAM GENERATING UNIT.

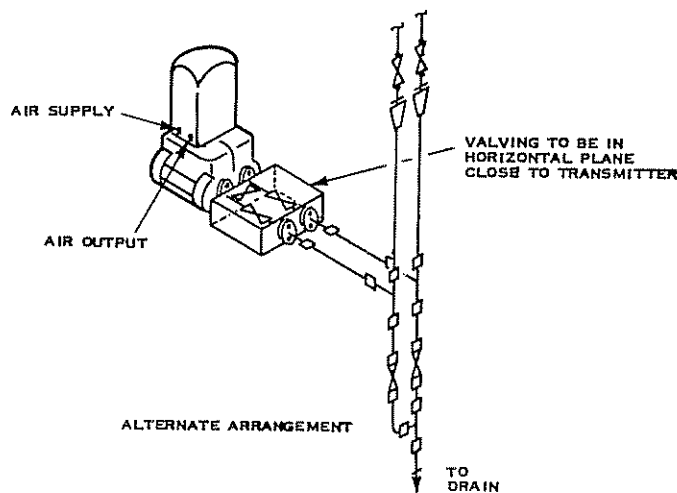
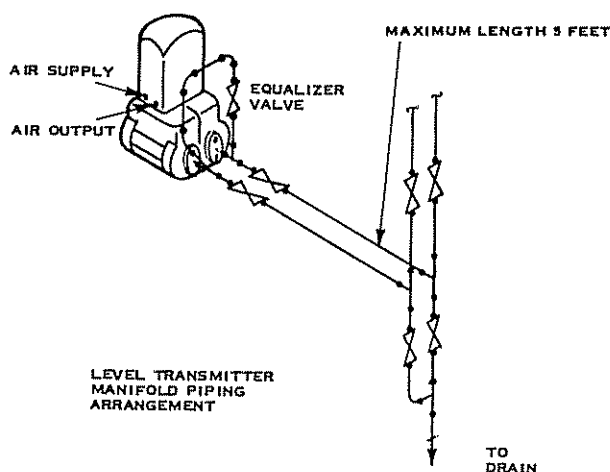
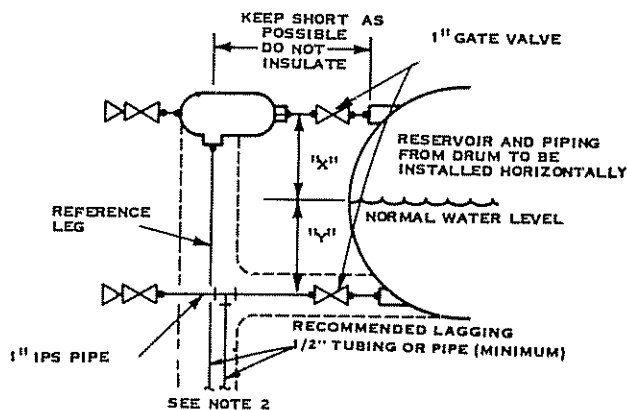


Figure 1-1—Typical Installation Drum-Level Transmitter Differential Pressure Type

### 1.2.3 FEEDWATER PRESSURE

Feedwater pressure is required for operator guidance and control. It is normally indicated and recorded on the steam-generator panel. On multiple steam-generator installations with common feedwater piping systems feedwater header pressure is sometimes regulated at some fixed value above the highest drum pressure. Refer to RP 550, Part I, Section 4 for installation.

### 1.2.4 SUPERHEATED STEAM TEMPERATURE

Superheated steam temperature is required for operator guidance and control. When control is used, it is primarily to prevent overheating the superheater and to assure safe conditions of auxiliary equipment. A resistance bulb, thermocouple, or filled thermal system can be used. The type of well and its immersion should be carefully selected and a special tapered well should be considered for high pressure and high velocity service. Tapered wells should be designed for the particular installation to prevent cracking from metal fatigue

caused by the wells vibrating at their natural frequency.\* For installation of temperature measuring devices, refer to RP 550, Part I, Section 3. Typically, wells in superheated steam service are welded in place.

### 1.2.5 DRAFT PRESSURE OF GASES AND AIR ENTERING OR LEAVING THE VARIOUS SECTIONS

Draft pressure is normally used for operator guidance. Diaphragm-type gages are usually used on these low pressures. The draft transmitter range should be sufficiently wide to cover unusual conditions. Sensing lines must be designed to assure fast response to small changes. Purge systems to prevent plugging may be necessary and, if used, care must be taken in this arrangement to be certain the gage is not subjected to purge pressures. Refer to RP 550, Part III, Section 1 for installation.

\*J. W. Murdock, "Power Test Code Thermometer Wells," *ASME Trans. J. Power Eng.*, 403-16, October (1959).

## 1.2.6 FUEL PRESSURE

### 1.2.6.1 Using Gas as the Fuel

When using gas as the fuel, main header pressure is normally measured and transmitted to the control board. The main header pressure is taken downstream from the master regulator to the fuel system. Pressure to the burners is also measured and transmitted to the control board. This measurement is made downstream of the fuel control valve. Sometimes pressure indication is desired between the burner and the burner cock. These, if desired, are normally furnished by the steam-generator manufacturer. For installation, refer to RP 550, Part I, Section 4.

### 1.2.6.2 Using Oil as the Fuel

When using oil as the fuel, Paragraph 1.3.6.1 applies except that a pressure-regulating valve is used on the discharge of the pump to regulate the maximum pressure. In a system where oil is recirculated and only part is going to the users, it is necessary to control the system pressure. This is done to properly proportion the flow to the burner and the return line. Refer to Figures 1-2 and 1-3 for a typical fuel oil piping system. In many installations, steam-atomizing oil burners are employed. This is primarily a function of burner design. When steam atomization is used, it is usually necessary to control differential pressure between the fuel and the steam. Refer to Figure 1-4. However, some burners require a constant pressure.

For installation of pressure measuring devices, refer to RP 550, Part I, Section 4. When using heavy oils for fuel, consideration should be given to heat tracing or seals if climatic conditions can cause a possible problem. For installing heat tracing or seals, refer to RP 550, Part I, Section 8; for further information on application of seals, refer to RP 550, Part I, Section 4.

## 1.2.7 ANALYSIS

### 1.2.7.1 Oxygen

In order to establish and maintain the efficiency and safety of the combustion process, excess air is an important measurement. A combustion control system is continually adjusting the fuel feed to meet the varying load requirements and maintaining a correct proportion of air to burn the amount of fuel that is being fed at any time. To obtain a good measurement relating to the quality of combustion, samples should be taken as near as possible to the point where combustion is completed. This will minimize air leakage that will tend to dilute the sample. To obtain the percent oxygen in the

flue gases, an oxygen analyzer is used. The analyzer may be used for recording, indicating, alarm, or control. If control is used, high-low limit relays should be installed. Some users limit the corrective control action to  $\pm 5$  percent of maximum air flow in the event of analyzer failure. Refer to RP 550, Part II, Section 19 for installation.

### 1.2.7.2 British Thermal Unit (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 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 products of combustion is compared with the air and gas temperature to obtain the Btu value. The other type comprises 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.

Probably the simplest inferential Btu measurement is direct density measurement of the gas. Refer to RP 550, Part II, Section 21 for installation of densitometers. The gas density can be correlated to heating value by laboratory calorimetry or by gas analyses and reference tables. Accurate correlation is difficult if the gas composition varies widely.

Probably the most sophisticated system is to use a gas chromatograph with its output fed directly to a computer programmed to calculate the heating value from the analysis.

### 1.2.7.3 Smoke Measurement

In some installations, smoke detectors are required. The equipment monitors smoke density by observation of a light beam projected across the flue. These instruments are usually comprised of a light source opposite a bolometer or a photo-electric 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 bolometer clean and cool. Otherwise, the reading will be too high. Air purging over the lenses may be required.

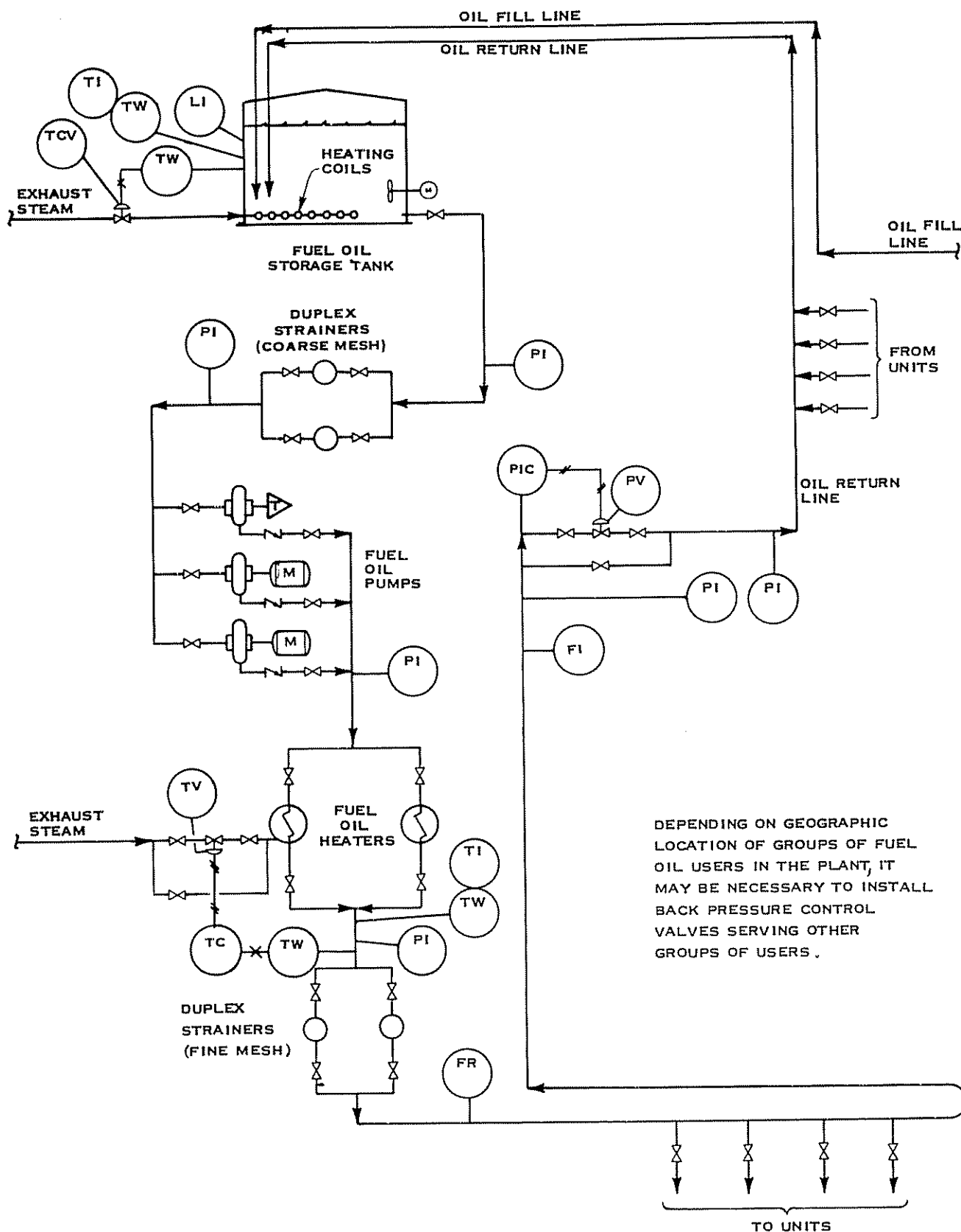


Figure 1-2—A Typical Plant Fuel Oil Circulating System

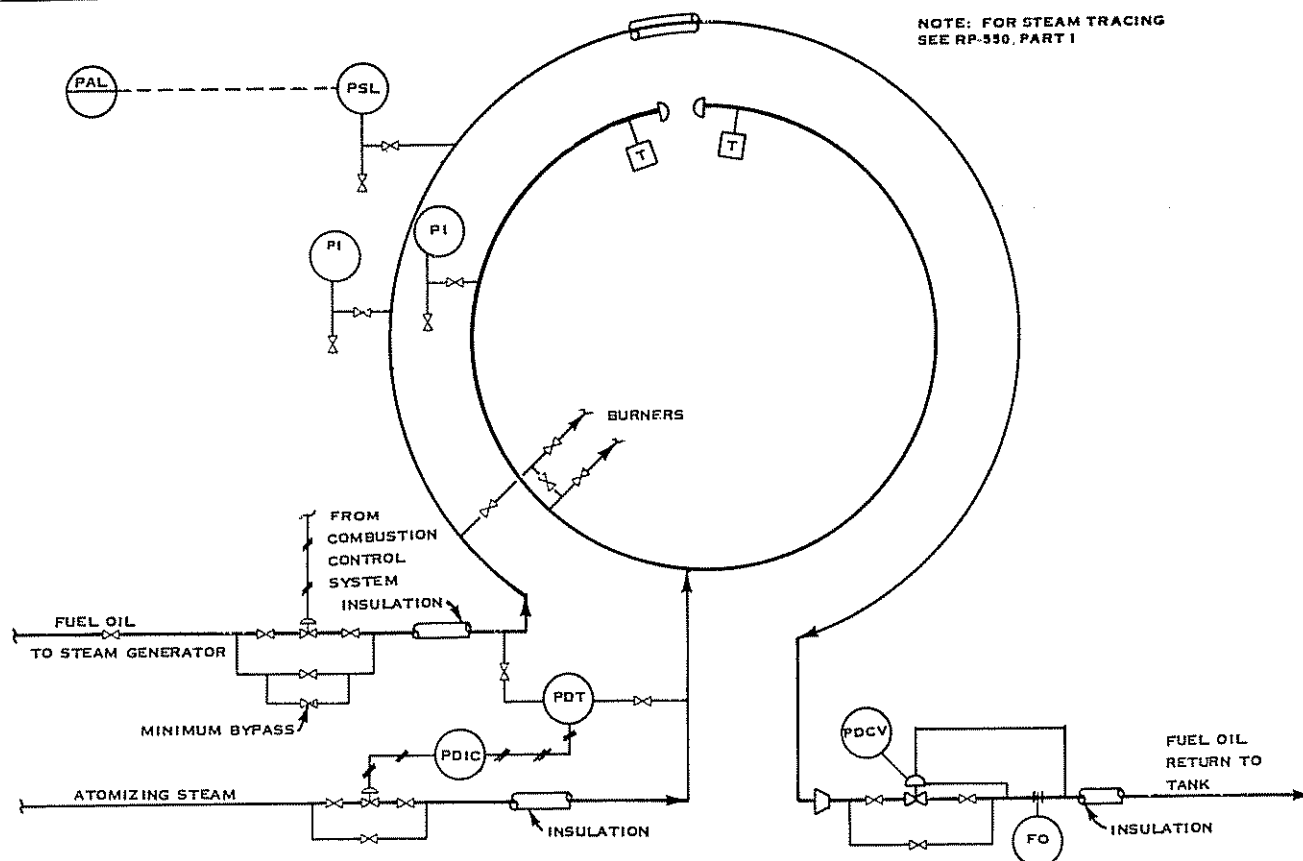


Figure 1-3—Typical Steam Generator Fuel Oil Circulation System

**1.2.7.4 Sulfur Dioxide ( $\text{SO}_2$ )**

Sulfur dioxide measurement should be considered. In some installations, sulfur dioxide analyzers are required.

**1.2.7.5 Nitrogen Oxides ( $\text{NO}_x$ )**

Nitrogen oxide measurement should be considered. In some installations, nitrogen oxide analysers are required.

**1.2.7.6 Combustibles**

This measurement should be considered.

**1.2.8 FEEDWATER TEMPERATURE**

Feedwater temperature can be detected by using a thermal system, resistance measurement, or thermocouple measurement, and is normally recorded. High feedwater temperature can cause flashing through the pumps and primary flow elements and in some installations may cause circulation problems leading to damage. Refer to RP 550, Part I, Section 3 for installation.

**1.2.9 FLUE GAS TEMPERATURE**

Flue gas temperature measurement can be made by

using an averaging-type preformed capillary (see Figure 1-5), a "sausage"-type flue gas bulb (see Figure 1-6), or one or more thermocouples (see Figure 1-7) placed in the duct. For thermocouple installation, refer to RP 550, Part I, Section 3. Minimum flue gas temperature is a function of equipment design. For recommended arrangements of temperature and gas sampling connections to steam-generator settings and ducts, refer to SAMA-ABMA recommended standard instrument connections.

Because of the sulfur present in most fuel oils, excessive corrosion and plugging of air heater and precipitator elements results in objectionably high annual maintenance costs when exit gases are cooled beyond their dew point. Some technique is generally used to assure that flue gases are not cooled below their dew point. This can be accomplished by preheating the air (using steam) by cold air bypass, or by flue gas recirculation. The actual determination of the flue gas dew point is very difficult and generally not considered for measurement. For some high sulfur fuel oils the flue gas temperature may need to run as high as 400 degrees Fahrenheit.

### 1.2.10 AIR TEMPERATURE

If desired, the same measurement can be made for air temperature as for flue gas temperature. In many applications, it is unmeasured and uncontrolled. However, when an air heater is used, air temperature is measured to hold it above a predetermined minimum value to maintain flue gas temperature from the air heater above the dew point.

### 1.2.11 FUEL TEMPERATURE

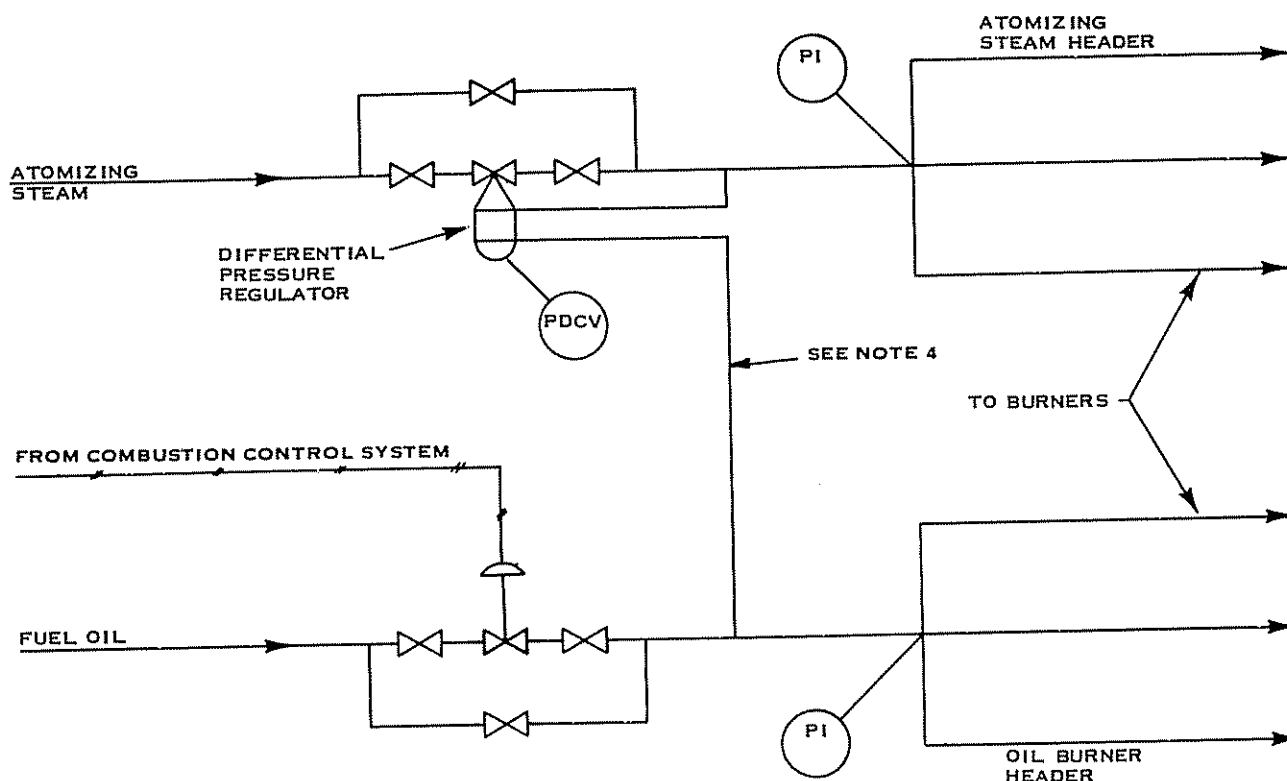
#### 1.2.11.1 Fuel Gas Temperature

Fuel gas temperature is not normally considered.

Where liquid carryover may be a problem, external means should be provided to knock out the liquid or heat the gas to a temperature above its dew point.

#### 1.2.11.2 Fuel Oil Temperature

Fuel oil temperature is usually measured and sometimes controlled. The measurement is generally made using a thermocouple, filled thermal system, or resistance bulb. The oil temperature required is dependent on the grade of oil being used. In the worst conditions (when using Bunker C or other heavy fuel), too low a temperature can cause a poor or dirty flame. Too high a temperature can cause carbonization of the burner tip.



#### NOTES:

1. DIFFERENTIAL PRESSURE REGULATOR SHOULD BE DOUBLE METALLIC DIAPHRAGM TYPE TO REDUCE POSSIBILITY OF CONTAMINATION OF STEAM SYSTEM BECAUSE OF RUPTURED DIAPHRAGM. TRANSMITTER TYPE SYSTEM MAY BE USED.
2. PNEUMATIC SYSTEM SHOWN MAY BE ELECTRONIC.
3. STEAM PRESSURE IS USUALLY MAINTAINED 10-20 PSI ABOVE OIL PRESSURE.
4. THIS LINE SHOULD NOT EXCEED 15 FEET, FOR STEAM TRACING, SEE RP-550, PART I.

Figure 1-4—Schematic Diagram of Typical Installation of Differential Pressure Regulator for Fuel Oil Atomizing Steam