

MANUAL
ON
INSTALLATION OF REFINERY INSTRUMENTS
AND CONTROL SYSTEMS

PART II—PROCESS STREAM ANALYZERS

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MANUAL
ON
INSTALLATION OF REFINERY INSTRUMENTS
AND CONTROL SYSTEMS

PART II—PROCESS STREAM ANALYZERS

THIRD EDITION
1977

OFFICIAL PUBLICATION



REG U S PATENT OFFICE

AMERICAN PETROLEUM INSTITUTE
Refining Department
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ON
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FOREWORD

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 in chemical plants, gasoline plants, and similar installations.

This third edition of Part II of the manual, represents the latest suggested or generally used practices in the installation of all the devices covered in the second edition plus additional information based on revisions suggested by many individuals and several organizations. (The first edition of the manual was issued in 1960, the second edition in 1965)

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.

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 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 the Refining Department, American Petroleum Institute, 2101 L Street, N.W., Washington, D.C. 20037.

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INTRODUCTION

Accepted methods for the permanent or semipermanent installation of analyzers in refining units are presented in this part of the manual. Analyzers which are used to monitor the characteristics of process streams either continuously or on a fixed-time cycle are described. The methods outlined herein are for use in processing units rather than in laboratories and are for permanent rather than temporary or portable setups. Selection, application, and economic justification of stream analyzers are outside the scope of this manual. General practices common to analyzer installations are discussed. More detailed recommendations are made for gas chromatographs; viscometers; distillation, flash, and vapor pressure instruments; moisture analyzers; oxygen analyzers; pH instruments; and densitometers.

Although the purpose of this manual is to cover widely used types of equipment, the practices described, also, will assist in the installation of less frequently used instruments. Part II primarily deals with sampling systems and the analytical portion of analyzers and other basic parts. For information pertaining to the installation of control, signal transmitting, or recording equipment, refer to Part I of the manual; see, especially, Sections 5, 7, and 12.

Before the preparation of this edition of Part II, careful consideration was given to the extent of the revisions necessary to update the manual. It was decided to approach the revision in two phases. The first phase would maintain the format of the 1965 edition and would update it to reflect the ideas and techniques of the past 10 years. This would provide the reader with an interim document to serve his needs until the second phase of the Part II rewrite was finished. The second phase, now underway, will consider publishing each section of Part II individually as has been done with Part I. In addition, certain sections will be reorganized and new sections added.

It is believed that this edition of Part II should adequately serve the user until the second phase rewrite is finished and published.

PART II—PROCESS STREAM ANALYZERS

SECTION 14—ANALYZERS

14.1 Scope

This section covers the application and installation of process stream analyzers. The intent of this section is to facilitate economical, trouble-free, and satisfactory installations. However, the recommended practices discussed cannot be considered as substitutes for expert skill and broad knowledge of the field.

14.2 General

14.2.1 SIGNIFICANCE OF ANALYZER INSTALLATION PRACTICES

Companies install process stream analyzers in order to obtain current information on stream composition or characteristics so that materials being processed can be used more advantageously in meeting product commitments. Properly applied and installed analyzers usually result in economical and trouble-free operation. Improperly applied and installed analyzers generally create maintenance and operating problems extending over long periods of time. Analyzer installations may be costly because considerable skill, experience, and painstaking attention to detail are required for successful operation.

14.2.2 STREAM ANALYZERS USED

Types of stream analyzers used in plant operations include those measuring—

1. Physical properties (normally used for product specifications):

- Boiling points (including initial and end points)
- Cloud point
- Color, turbidity or opacity
- Conductivity
- Density or specific gravity
- Flash point
- Freeze point
- Octane
- Pour point
- Vapor pressure
- Viscosity

2. Chemical properties:

- Acid strength
- Catalytic or chemical activity
- Combustibility
- Dissolved oxygen

- Electrolytic effects

- Hydrogen ion concentration (pH)

- Moisture content

- Oxidation-reduction potential

- Salt in crude

- Specific ion

- Total organic carbon

- Total oxygen demand

3. Stream compositions by:

- Chromatography

- Dielectric constant

- Magnetic effects

- Chemiluminescence

- Flame ionization

- Mass spectrometry

- Radiation (beta or gamma)

- Refractive index

- Spectroscopy (infrared, ultraviolet, x-ray)

- Thermal conductivity

These groupings are arbitrary, nonexclusive, and in some cases overlapping. Most analyzers measure gas or liquid streams. Some measure properties of solids, such as catalyst adsorption, or the carbon or moisture content of catalysts.

14.2.3 INSTALLATION DESIGN CONSIDERATIONS

Many factors are involved in providing a complete analyzer system. The installation must—

1. Meet all safety requirements;
2. Make certain that the objective—an accurate, reliable analysis—can be attained;
3. Provide facilities for necessary testing, calibration, and isolation (valves, switches, and so forth) and for economical maintenance; and
4. Be designed for lowest cost commensurate with required performance.

14.2.4 PURPOSE OF THE INSTALLATION

It is important to state precisely why the analyzer is being installed so that all personnel (engineering, laboratory, installation, operating, and maintenance) are informed of the purpose and final objective of the installation. For example, essential information should include the following:

1. The stream(s) to be sampled (with the name and location of each stream clearly specified) and the data to be obtained;

2. The objective of the installation:
 - a. Operator information only
 - b. Operator information and his corrective action
 - c. Direct process control
 - d. Study information
 - e. Management information

14.2.5 PREASSEMBLED SYSTEMS

Preassembled analyzer systems are generally convenient and economically attractive. They may include one or more analyzers with sample conditioning and utility connections mounted on a frame or housed in a shelter, or both. There are several advantages in this type of construction:

1. Systems designed and factory constructed by a specialist supplier often may be superior to those normally produced on site.
2. Factory construction is independent of weather and labor conditions at site.
3. Systems can be fully tested under simulated operating conditions and major design, equipment, and construction faults corrected before delivery to site.

14.3 Safety Considerations

Analyzer installation safety problems may require considerable engineering study. Some of the electrical, ignition, and safety factors are discussed in 14.3.1 and 14.3.2.

14.3.1 ELECTRICAL AND IGNITION POSSIBILITIES

Petroleum hydrocarbon sample streams may be analyzed in enclosures which also contain analyzer electrical equipment and arcing devices. Failure or maloperation of the electrical equipment can provide a source of ignition. The *National Electrical Code* [1]* does not cover these situations thoroughly. Thus, adequate groundwork must be laid, before actual equipment installation is made, to assure that there will be no difficulty in meeting inspection requirements. From a practical viewpoint there are several ways to handle this problem. The best selection depends upon many factors which include the following:

1. Whether the atmosphere at the analyzer location is likely to contain flammable material in explosive or ignitable portions with air, and whether this condition exists normally or only as the result of an abnormal condition (for example, equipment failure)
2. Whether or not it will be necessary to open the enclosures with the units energized
3. Whether any portion of the electrical or analytical system is normally, or abnormally, apt to be at a temper-

ature above 80 percent of the ignition temperature (in degrees Celsius) of flammable materials expected or likely to be present; or whether electrical sparks or other ignition sources may be present during operation of the analyzer

4. Whether it is practical to confine the ignition sources in explosion-resistant enclosures, hermetically seal them (as in hermetically sealed relays), or otherwise isolate them from potentially explosive or ignitable materials or atmospheres.

The installation designer should be familiar with the requirements of national and local codes applicable to the proposed location of the analyzer. Helpful guidance may be obtained from API RP 500A, *Classification of Areas for Electrical Installations in Petroleum Refineries* [2], ISA RP 12.1, *Electrical Instruments in Hazardous Atmospheres* [3], and ISA RP 12.2, *Intrinsically Safe and Non-Incendive Electrical Instruments* [4]. Suggestions for the use of electrical instruments in potentially hazardous atmospheres may be found in ISA S12.4, *Instrument Purging for Reduction of Hazardous Area Classification* [5]. References 6 and 7 contain much of the background developed by the Instrument Society of America upon which these practices are based; see also the appendix of Reference 8. A few electrical instruments, current- or energy-limited, may be intrinsically safe, that is, the portion of the electrically energized equipment and wiring which is in a potentially hazardous location is incapable of releasing sufficient energy under normal or abnormal conditions to cause ignition of the specific hazardous atmospheric mixture. Many thermocouple circuits and some capacitance analyzers are examples.

Some analyzers are fully enclosed in properly sealed explosionproof housings. Others have their electrical equipment isolated and so enclosed. Still others may be installed in metal housings located in a potentially hazardous area and protected from the external atmosphere by purging, sealing, or submergence. The installation designer must ensure against loss of purge medium and against overheating of the external case (such as could occur when a loose wire shorts to a ground).

Preventing or confining internal explosions may still be a problem. Inasmuch as the sample itself may produce a combustible mixture in the analyzer, it may be necessary to house the analyzer in an explosionproof case even though it is located in a nonhazardous area.

Another approach is to continuously purge the analyzer case with enough nonhazardous gas or "safe" air to sweep out flammable materials before they can build to unsafe concentrations. Air should not be used unless it can be determined that there is no danger of producing an explosive mixture. Purge requirements vary ac-

* See Reference list at end of section.

cording to the purge classifications for the installations. Purge classifications are defined in ISA S 12.4, from which excerpts from Section 3 are presented herein as an aid, as well as a reminder, for the installation designer.

3.3.1 Type Z Purging. Covers purging requirements adequate to reduce the classification of the area within an enclosure from Division 2 (normally non-hazardous) to non-hazardous.

3.3.2 Type Y Purging. Covers purging requirements adequate to reduce the classification of the area within an enclosure from Division 1 (hazardous) to Division 2 (normally non-hazardous).

3.3.3 Type X Purging. Covers purging requirements adequate to reduce the classification of the area within an enclosure from Division 1 (hazardous) to non-hazardous.¹

Type X involves the greatest risk. The external atmosphere may be hazardous at any time and a source of ignition may simultaneously exist within the case. If the purging system fails, the equipment must immediately be de-energized to avoid a possible explosion.

When an analyzer can be a continuous source of atmospheric ignition, thought must be given to providing for its maintenance and protection against mechanical damage, case corrosion, inadvertent opening of cases, and so forth. Adequate interlocks should be provided along with warning signs designating safety precautions to be followed. For example, when planning the installation of a chromatograph employing peak-holding capacitors, provision should be made for discharging these capacitors before instrument enclosures are opened. Alternatively, these capacitors are often in the analyzer control chassis which is located in a general purpose area.

Sample lines leading to, as well as inside, the explosionproof case should be assembled with the highest quality material and fittings. Frequent checks should be made for leaks.

The electrical system should be installed with the highest grade components. Twisted and taped joints should be used only where it is impossible to use superior types of splices. Signal wires should not be spliced.

Many analyzer systems contain spark-generating devices such as relays. When it is not necessary to locate these units at or near the sample source, they may be mounted in hydrocarbon-free areas.

14.3.2 SAMPLE DISPOSAL

Safe disposal of sampled process material, which cannot be economically returned to the process system, is a prime consideration. Piping should be provided so that

vapors can be vented to a safe location or liquids can be drained in a clean and orderly fashion to a safe point. Small amounts of light hydrocarbon vapors when properly discharged into the atmosphere will diffuse rapidly to less than the minimum explosive concentrations. Such venting systems may be preferable to discharging vapors into closed systems where back pressure may occur sporadically. Toxic vapors should not be vented directly to the atmosphere. All venting systems should conform to the limits established by regulatory groups.

14.4 Analyzer Location

Sampling problems may be minimized by locating the analyzer as close as practicable to the sample point. In some cases, it is essential to locate the analyzer right at the sample point with the minimum practicable sample line length. When monitoring a sulfur plant, for example, off-gas, sulfur dioxide (SO_2), and hydrogen sulfide (H_2S) may continue to react forming sulfur in the sample line, possibly causing erroneous readings or plugging of the line.

The analyzer components must be protected from (a) hot equipment, (b) severe ambient temperature changes, or other vagaries of the weather, (c) shock, (d) vibration, and (e) mechanical damage. Because many analyzers are sensitive to or damaged by vibration, such conditions should be avoided when selecting the analyzer location. This is not difficult in an existing plant. In a new plant, proximity to heavy reciprocating equipment and locations near highways, railroads, and processes where intermittent movement of solids produces earth tremors should be avoided. Shock mountings should be used where vibration is unavoidable.

Many analyzers require weekly maintenance, and in some instances daily maintenance is required. Good installation practices can save manhours and improve reliability.

The analysis cell location should be conveniently accessible, whether at grade or at some elevated point. Accessibility may be provided by allowing space for portable platforms or by installing permanent platforms. Avoid installations where a ladder would be necessary.

Even in the most benevolent climate, a roof over the instrument is justified to protect service personnel and equipment from thundershowers, process and water spills, falling objects, and sunlight. In some cases, shielding against radiant heat from surrounding equipment must be provided. Normally, housing requirements increase with climatic severity. In some installations, lighted, heated, and ventilated housings, preferably of the walk-in type, will be desirable. See RP 550, *Manual on Installation of Refinery Instruments and Control*

¹ ISA S12.4, *Instrument Purging for Reduction of Hazardous Area Classification*, Instr. Soc. Am., Pittsburgh, Pa., p. 4, 1970.

Systems, Part I, Section 8—Seals, Purges, and Winterizing for information on weather protection. The term "housing" as used in this section is in the same context as in Section 8.

Housings should be located to avoid explosion hazards. Due to their construction, many analyzers must be considered small explosive areas that are rendered nonhazardous by their enclosures. Frequently, troubleshooting and repair can be expedited by removing the bells or covers from the enclosures and observing operation of the internals with electric power turned on. Location in nonhazardous or Division 2 areas permits this procedure. It is advisable, however, that all such houses, regardless of location, be equipped with prominent signs warning that safety checks should be made with a portable explosimeter both before and after opening the enclosure or that a combustible gas alarm be installed permanently within the house. In Division 1 areas this procedure is prohibited. Therefore, the instrument must be moved to a safe location before repairs can be made. To transport it with necessary caution, the unit should be mounted on a rack equipped with feet, which can be adjusted for mobility. Walk-in analyzer buildings (housings) should be provided with exits so located as to permit safe evacuation in the event of an emergency within the process area.

Material selected for the construction of the house should be of a type that will not cause operational difficulties nor create a safety hazard. For example, a house constructed of sheet aluminum can absorb enough heat on a hot sunny day to raise the temperature of the analyzer enclosure higher than that of the thermostatic control point, thus causing false readings and malfunctions. A house constructed of cement-asbestos material can be a source of shrapnel if it is exposed to fire or explosion.

14.5 Sampling Systems

A major problem in most analyzer installations concerns supplying the analyzer with a sample which is continuously representative of the process stream and compatible with the analyzer used.

A representative sample is one that has been correctly taken from the process stream and conditioned without altering the variable factor to be measured. A sample which is suitable for measurement will not alter or adversely affect the analyzer's accuracy. Such a sample may have been treated, for example, to remove a material which would corrode or plug the analyzer but is still representative with regard to the property to be measured.

Analyzer streams may be drawn continuously or intermittently. Frequently, one of more fast moving by-

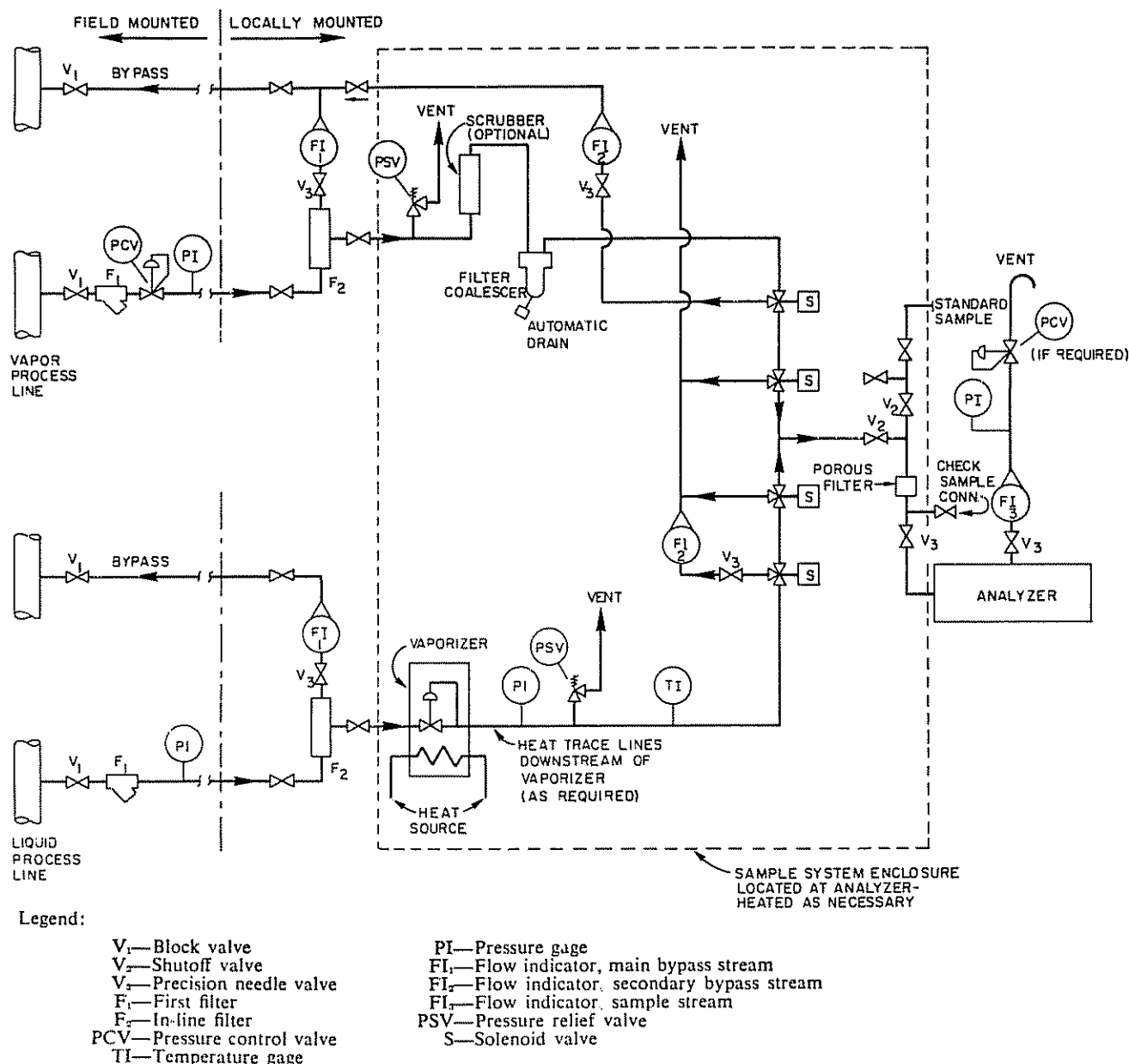
pass streams are circulated past the analyzer location (see Figure 14-1) so that a small sample may be directed into the analyzer continuously or periodically. Such use of a bypass flow loop past the analyzer allows time lag reduction without a need for excessive velocity in the sample line to the analyzer. Some analyzers measure continuously, others handle samples periodically. Either type may be connected, in turn, to one of several streams to provide for the analysis of the several streams using one analyzer. This practice necessitates careful design engineering based on experience and the manufacturer's recommendations. Depending on the requirement of the analyzer application (on closed loop control or for alarm or shutdown, or both) and the overall timing and difficulty of analysis, it may be preferable to avoid multistream analysis using one analyzer. Experience has indicated the necessity of considering stream flow rate, pressure, temperature, corrosivity, cleanliness, consistency, phase, and dewpoint. These factors must be taken into account even though the installation is no more complex than inserting a capacitance probe into a pipe or a vessel.

There is no single simple solution to the sampling problem and no universal system suitable for most applications. Each installation, or type of installation (see 14.5.1 through 14.5.7), has its own problems and requires individual study before accurate analysis can be expected. Experience has shown that the study will prove valuable in providing reliable data and in reducing maintenance.

14.5.1 SAMPLE-POINT LOCATION

Although process characteristics govern the stream to be analyzed, there is usually a choice as to the physical location of the sample point. Preferably, sample points should be located to—

1. Provide a clean, representative, and measurable sample of the process stream, as influenced by the corrective action (action taken by the operator or by controlling valves and so forth to regulate the stream property measured) (Avoid sampling of any multiphase process system.)
2. Reduce the process time lag between the point in the process where corrective action is applied (for example, control valve location) and the sample point (Sample lines should be kept short to reduce the time lag between the sample point and the analyzer.)
3. Provide a clean, dry sample (except where moisture is a required factor in the analysis) to minimize the need for filters, dryers, knockout traps, and steam tracing
4. Obtain the sample at moderate pressure and temperature conditions to reduce requirements for pressure-reducing valves, sample coolers, or heaters



NOTE: All vents and drains terminate outside of enclosure. Also see text for safe disposal.

Figure 14-1—Typical Multiple Stream Sampling Systems

5. Allow convenient access to the sample location
6. Provide means for obtaining laboratory check samples from the sample line immediately upstream of the analyzer.

A poorly located sample point usually provides a non-representative sample and can cause entrainment of foreign matter. Also, such a location may cause excessive time lags or plugging or may make a calibration check difficult or impracticable.

A sample point close to the junction of two streams may provide a sample which is not thoroughly mixed. Sampling downstream from a pressure reducing valve may give mixed-phase problems. Entrainment may be minimized by properly locating the sample tap. The tap should be located on the side of the line to minimize liquid or dirt entrainment for vapor samples and to reduce dirt and bubbles in liquid samples. Sometimes a probe (see Figures 14-2 through 14-4) is used to with-

draw the sample from the center of the line to avoid contamination from material carried on the inner surface of the pipe. A probe inserted through a packing gland and block valve, if permitted by piping specification, can be of value when removal of the probe is required for cleaning or for performing a sampling traverse. Designs using probes must consider maximum allowable velocity to prevent vibrational failure, provide blow out protection, and allow probe inlet orientation.

Sample lines should be routed as directly as possible and, in the case of gas sampling, in such a manner as to avoid trapping of liquid or contaminating particles.

When monitoring a fractionator, there is usually a place in the column that will show greater or faster composition changes than those that occur in the product stream. A sample from this location will often provide more responsive control. Perhaps the requirements of the application will make analysis desirable at two points—one to monitor product purity, the second to provide faster control. The sample location for overhead product control is between the feed tray and the tower top; for bottom product, it is between the feed tray and the tower bottom. Sometimes a computer is used to calculate fractionating conditions for guidance in locating the sample point. However, this choice may be incorrect if conditions or end use of the data change.

14.5.2 SAMPLE CONDITIONING

It is safe to assume that process stream samples will contain contaminants. Some samples must be chemically treated to remove or inactivate contaminants; however, this may cause other problems from the reactants. Often liquid samples must be vaporized, and vapor samples must be heated to prevent condensation or possible deposition of dissolved solids (see RP 550, Part I, Section 8). The line between a vaporizer and the analyzer must be heated to maintain a temperature higher than the dewpoint. Some materials may polymerize or react chemically when heated. When gas pressure is sharply reduced some samples may freeze, deposit ice, or form hydrates due to refrigeration effect. Frequently, both the sample and analyzer temperature and pressure require close regulation. Usually the sample flow rate, or sampling quantity and frequency, must be closely controlled. Neglect by the installation designer of any one of these requirements may result in an erroneous analysis or no analysis at all.

Most refinery streams are water saturated, therefore, unless the moisture content is to be measured or the component to be measured is soluble in water, moisture removal usually must be provided. Entrainment separators or coalescers will remove water droplets. However, special precautions may be needed when water in solution or water vapor is to be removed. For example, water accumulation in an initial boiling point analyzer would cause the readout to be meaningless.

Where saturated vapor samples are transported through an area where ambient temperature is lower than the temperature at the sample inlet point, the sample line should be heat traced or jacketed to avoid formation of condensate.

14.5.3 STANDARD SAMPLES

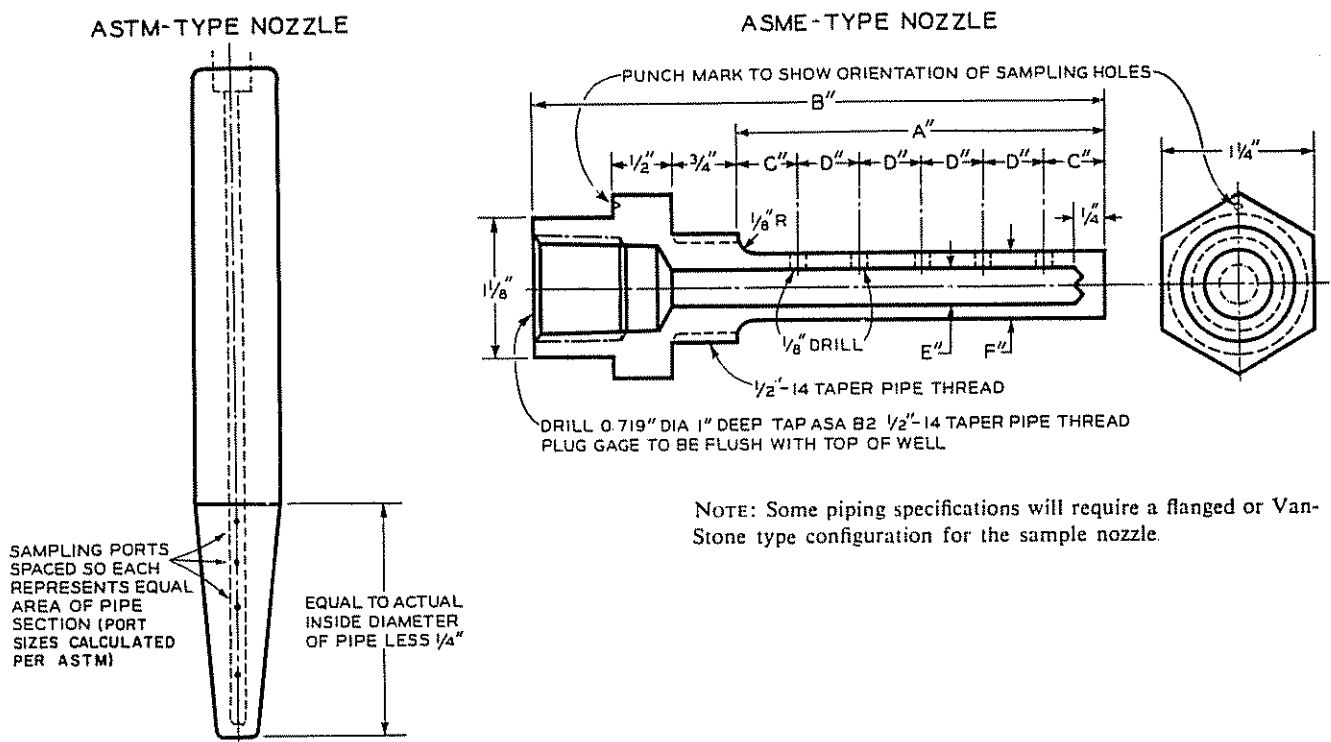
Standard samples are usually laboratory or commercially prepared volumes of gases or liquids which contain known quantities of the component or components which the analyzer was designed to detect. Such samples must be uniform, representative, and stable. The sample should be kept under conditions which will not cause changes in the analyzed properties. These values can change because of evaporation, polymerization, stratification, contamination, and so forth. Storage conditions should be selected for each particular type of sample.

Standard samples must be obtained from a reliable source, and it is advisable to have the control laboratory run initial and periodic analyses of the standard sample. This often helps point out direct correlations between laboratory readings and process readings and is a quick method of troubleshooting. Determination of absolute values for standard sample components can be a serious problem because of the difficulty in obtaining repeatable laboratory results. Therefore, the average value from a number of laboratory analyses may be required to provide a reasonably accurate value for the standard sample.

Checking or calibration of analyzers can be accomplished more easily if, in the original installation, provisions are made to supply a standard sample to the analyzer (see Figure 14-1). This may permit the process unit operator to make sure the analyzer is recording accurately.

14.5.4 USER-SUPPLIER RELATIONSHIPS

It is essential to carefully review sample requirements with the analyzer supplier. This helps avoid trouble which may develop from the user's failure to fully understand the equipment or from the supplier's failure to fully understand the application. With the analyzer, the supplier may also furnish all the equipment needed to properly condition and regulate the sample. It is necessary to carefully define all conditions of operation, all components of the process stream sampled, and all variations of sample composition. Furthermore, it is necessary to obtain realistic assurance that the supplier com-



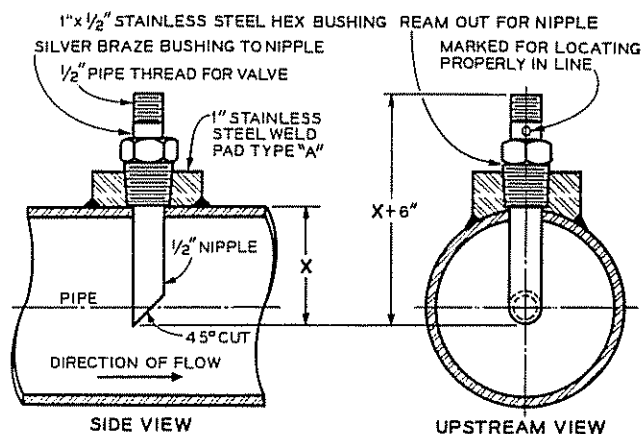
Number of ports for ASTM-type nozzles are as follows:

Inside Diameter of Pipe (inches)	Number of Ports
2 to 6	4
Over 6 to 12	6
Over 12	8

STANDARD ASME TYPES OF NOZZLES

Steam Line		Sampling Nozzle						
Nominal Size (inches)	Internal Diameter (inches)	Outside Diameter F (inches)	Bore E (inches)	Length		Quantity	Sampling Holes	
				A (inches)	B (inches)		C (inches)	D (inches)
2	1.939	0.540	0.300	13 $\frac{1}{4}$	35 $\frac{3}{8}$	3	5 $\frac{3}{8}$	1 $\frac{1}{2}$
2 $\frac{1}{2}$	2.323	0.540	0.300	2	37 $\frac{3}{8}$	3	1 $\frac{1}{2}$	1 $\frac{1}{2}$
3	2.9	0.540	0.300	23 $\frac{1}{4}$	45 $\frac{3}{8}$	5	3 $\frac{3}{8}$	1 $\frac{1}{2}$
3 $\frac{1}{2}$	3.364	0.540	0.300	3	47 $\frac{3}{8}$	5	1 $\frac{1}{2}$	1 $\frac{1}{2}$
4	3.826	0.540 or 0.675	0.300 or 0.437	35 $\frac{3}{8}$	51 $\frac{3}{8}$	6	9 $\frac{1}{16}$	1 $\frac{1}{2}$
4 $\frac{1}{2}$	4.290	0.540 or 0.675	0.300 or 0.437	4	57 $\frac{7}{8}$	6	7 $\frac{1}{16}$	5 $\frac{3}{8}$
5	4.813	0.540 or 0.675	0.300 or 0.437	47 $\frac{3}{8}$	61 $\frac{3}{8}$	6	7 $\frac{1}{16}$	3 $\frac{1}{4}$
6	5.761	0.540 or 0.675	0.300 or 0.437	51 $\frac{3}{8}$	73 $\frac{3}{8}$	6	7 $\frac{3}{8}$	3 $\frac{1}{4}$
8	7.625	0.540 or 0.675	0.300 or 0.437	71 $\frac{1}{2}$	93 $\frac{3}{8}$	6	5 $\frac{3}{8}$	11 $\frac{1}{4}$
10	9.75	0.675	0.437	91 $\frac{1}{2}$	113 $\frac{3}{8}$	6	3 $\frac{3}{8}$	13 $\frac{1}{4}$
12	11.75	0.675	0.437	111 $\frac{1}{2}$	133 $\frac{3}{8}$	7	1 $\frac{1}{2}$	13 $\frac{1}{4}$
14	13.0	0.675	0.437	121 $\frac{1}{2}$	143 $\frac{3}{8}$	7	5 $\frac{3}{8}$	17 $\frac{1}{8}$
16	14.75	0.675	0.437	141 $\frac{1}{4}$	161 $\frac{3}{8}$	8	9 $\frac{1}{16}$	17 $\frac{1}{8}$
18	16.5	0.675	0.437	16	177 $\frac{3}{8}$	8	17 $\frac{1}{16}$	17 $\frac{1}{8}$
20	18.5	0.675	0.437	18	197 $\frac{3}{8}$	9	1	2

Figure 14-2—Examples of ASTM and ASME Types of Nozzles



Line Size (inches)	"X" Diameter (inches)	Mark No.
3	2 1/4	A
4	2 1/4	B
6	3 1/4	C
8	4 1/4	D
10	5 1/4	E
12	6 1/4	F

NOTE: All nipples are to be seamless, extra heavy stainless steel

Figure 14-3—Typical Gas Sample Probe

pletely understands the problem and will furnish equipment fully suitable for the application.

It is very advantageous to the purchaser of an analyzer to send unconditioned samples, in sufficient quantity, to the supplier so that he can operate the analyzer in his laboratory on the actual process stream material. This will enable him to determine what equipment is necessary for sample conditioning and to check the ability of the analyzer to handle the raw or conditioned sample material. Equally important are the records the supplier produces. These records should be given to the people responsible for analyzer operation and maintenance. They are a most valuable reference for startup procedures and for solving future operational problems. Chromatograms and boiling-point-analyzer records can be especially helpful to the user of this type of equipment.

Transferring sample system design responsibility to the supplier may cause trouble. Usually a middle course is best—combining the design abilities of the user, installer, and supplier—so that the instrument receives a correctly conditioned sample to ensure satisfactory performance. Care should be taken to fully define the system responsibilities.

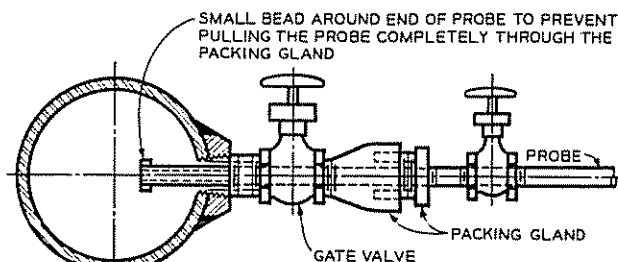


Figure 14-4—Special Gas Sample Probe

14.5.5 SAMPLING SYSTEM COMPONENTS

Equipment used in sampling systems may include pumps, ejectors, regulating valves, solenoid valves, flowmeters, sample coolers or heaters, filters, coalescers, dryers, knockout traps and trap legs, manifolds for switching samples, and timing equipment. Those responsible for the installation design must consider not only the materials of construction, but also the sizing and the location of these components. A sampling system must be assembled with the minimum number of parts compatible with proper transportation and conditioning of the sample. Extra components should not be supplied on the theory that they may be needed later because they increase the volume, lag, and servicing problems of the system. Particular care must be exercised to avoid introduction of excessive lag time in applications where the analyzer is used for control.

Each sample loop of a multiple-stream system must be considered as if it were the only sample to the analyzer. A careful study of all loop components will show which units can be used in common with all streams and which units must be isolated when the switching valve is actuated.

14.5.6 SAMPLING SYSTEM MATERIALS

By properly selecting materials for construction of the sampling system, a designer can avoid the following:

1. Reaction of materials with the sample
2. Absorption of components from the sample
3. Entrance of contaminants through osmosis or diffusion
4. Leaching material from the sampling system components
5. A fire hazard or other unsafe condition

When monitoring for trace constituents, some of these effects seriously reduce and even destroy the reliability of the analyzer's output. The following precautions should help to minimize such problems:

1. Use stainless steel tubing where practicable. (Be certain that the tubing is clean and grease-free before use.)
2. Protect sample tubing from mechanical abuse.

3. Design the sampling system to be pressure tight as determined by requirements.

FOR EXAMPLE: Molecular size leaks have been known to allow oxygen to diffuse into a sample stream when the partial pressure of oxygen in the sample was below that of air. This has been reported at pressure levels as high as several thousand pounds. Moisture can diffuse into a pressurized system in a similar manner. [9]

4. Examine each component in the system—such as filters, pressure regulators, valves, and flow controllers—for materials which may react with or absorb the sample.

FOR EXAMPLE: In one installed sampling system, a sample containing not more than 500 parts per million of hydrogen sulfide required from 3 to 7 days to reach equilibrium because the hydrogen sulfide reacted with components of the sampling system.

When pipe thread compounds are used, care should be taken that surplus quantities are not forced into the system. Sealing compounds either in liquid or paste form, or even in tape form, should be applied only to male pipe threads. Use of socket or seal-weld connections is frequently desirable. However, the designer should know that such connections leave small internal cracks or pockets in the pipe wall in which contaminants can accumulate.

Many pressure regulators, flow controllers, and the like contain absorbent diaphragms, or small cork or felt filters. When measuring low-moisture content or highly absorbent material, such as alcohol and solvents, these elements should be removed or replaced, otherwise the sampling system may require a long period of time to reach equilibrium. To prevent the possible loss of sample by absorption, metallic or ceramic filters should be used in preference to fiber or paper filters. It is recognized, however, that on special applications the fiber or paper filters are the superior choice.

14.5.7 SIZING COMPONENTS

The volume of the sampling system must be kept to a minimum and the flow velocity in the sampling system must be as high as is practicable consistent with required flow and permissible pressure drop. This is necessary so that the analytical system will have adequate speed of response to fluctuations of the measured variable in the process stream. Large sample lines introduce long time lags. Low velocities permit entrained liquid or foreign material to settle in the line which may eventually cause plugging. Good design velocity for flow through sample tubing has been found to range between 5 and 10 feet per second. Sample line tubing as small as 1/8-inch OD is frequently used on clean samples.

Dryers and filters should be as small as practicable and still perform their function. Large sizes increase lag time, cause back-mixing from diffusion, and delay the instrument's response to an actual change in sample composition. When a liquid sample is to be vaporized, it is especially important to minimize the dead ended liquid volume upstream of the vaporizing regulator.

With gas systems where long sample lines cannot be avoided, a pressure reduction to a level lower than that of the process at the sample point may be advantageous. A reduction in the pressure increases flow velocity and reduces the time required for gas to reach the analyzer. [10]

Sampling systems have been specially designed so that flow rates in the system (as distinguished from flowing quantities) were high. In order to reduce the time needed for transporting a sample from the process equipment to the analyzer, the volumes of knockout traps, filters, tubing, and valves were made as small as reasonable. Designers have gone even further in the case of chromatographs. By specially designing analyzer components, they have greatly reduced the size of the sample required. These designs have decreased the response time by a factor of ten or more over previously installed units.

14.6 Filtration [11]

As a general rule, all sampling systems should contain suitable filters. Self-cleaning bypass type filters are often used.

It is the responsibility of the installer to provide protection for the sampling system. Most sampling systems will have one or more pressure regulators, flow controllers, orifices, or other devices with flow restrictions needing the protection of a filter to remove solid matter and prevent plugging.

The selection of a filter that will prevent the plugging of a sampling system, which includes the filter itself, requires a knowledge of the physical and chemical conditions of the sample. For example, the porosity of the filter surface must be small enough to stop any solid particles that could cause plugging but not so small that the filter will readily foul. The length of service expected from the filter depends upon the percentage of solid particles in the sample stream, their size, the sample flow rate, and the surface area of the filter.

Cellulose cartridge types of filters may be satisfactory, provided the cellulose does not absorb some component of interest. In general, these filters will remove particles as small as 3 microns at pressure differences up to 100 pounds per square inch gage. Ceramic or porous-metallic types of filters also have been used satisfactorily in

sampling service. Ceramic and metallic-plate types of filters are available to trap particles from approximately 13 microns in size and larger. Sintered-metallic filters are available to trap particles as fine as 2 microns in size. Some models of either type are constructed so that only a portion of the total stream passes through the filter element. The remainder of the stream acts as a flushing medium to keep the internal filter surface clean.

When anticipating a high content of solids in a sample stream, installation of filters in parallel—with means provided for the isolation of each filter—is recommended. Motorized self-cleaning filters or automatic blowback systems may be considered. Important considerations are the accessibility and interchangeability of the filter elements.

14.7 Entrainment Removal [11]

Entrainment may be minimized through proper sample tap location (see 14.5.1). However, entrainment may occur even though the best tap location available has been selected. Entrainment can be in the form of liquid droplets in gaseous sample streams or in the form of gas bubbles in liquid sample streams. Water droplets can be entrained in most streams. Very few analyzers, if any, can tolerate entrainment. Therefore, entrainment removal should be of primary concern.

14.7.1 ENTRAINED LIQUID

Many gas samples contain droplets which are not a representative part of the sample. Sometimes these droplets are well dispersed and must be removed. Numerous methods for the removal of entrained liquid are available, including cold traps, baffles, sintered disk filters, or centrifuges. The entrainment separator shown in Figure 14-5 is perhaps the simplest and most widely used.

In this system, the gas enters the separator near the top and flows down through the packing to within 3 or 4 inches of the bottom. There the gas flow reverses direction, passing up through the tubing connected to the sampling system. As the gas passes through the packing, the small liquid droplets collect on the fibers. The droplets continue to collect and agglomerate until they are large enough to break away from the fiber. The larger drops of liquid fall to the bottom where they are accumulated and disposed of. Disposal is usually accomplished by means of an automatic float valve.

14.7.2 ENTRAINED GAS

A similar system, shown schematically in Figure 14-6, can be used to remove entrained gas bubbles from a liquid stream. For this service, the liquid enters near the bottom of the separator and flows with the entrained gas bubbles up through the packing. The gas bubbles

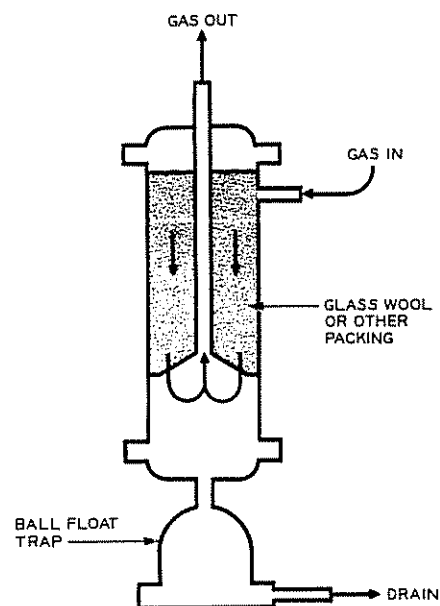


Figure 14-5—Entrained Liquid Separator

collect and agglomerate on the packing, forming large bubbles which break away and continue on to the top, where the gas is separated from the liquid and vented from the sampling system.

14.8 Scrubbers and Chemical Treatment [11]

Sample streams may contain corrosive gases and condensable vapors which can cause inaccuracies of measurement and may even damage the instrument. These and other sample contaminants can be removed by passing the sample stream through a liquid solution. Scrubbers, as these devices are called, take many forms. Some contain only a liquid solution; others use packings, such as beads, shot, and rings in addition to the liquid solution; still others use such mechanical devices as mixers or stirrers to provide more intimate contact of the sample streams and the liquid solution. Beds of solids (for example, caustic pellets) also have been used to prevent entrainment. Varied combinations of these methods are currently in use. The complexity of the scrubber system is dependent upon the needs of the application.

14.8.1 SPARGERS

The scrubber shown in Figure 14-7 is the sparger type in which the gas is made to enter the scrubbing medium through a sintered disk. Because of the small holes in the sintered disk, the gas breaks up, or separates, into small bubbles. The smaller the bubble, the greater the liquid-to-gas contact per unit volume of gas, which, in turn, produces greater scrubbing efficiency. The small bubble size tends to cause foaming, and there may be a

carryover of liquid droplets. The gas velocity should be kept low to avoid such lift effects. However, the use of an entrainment separator following the scrubber will remove the liquid droplets.

14.8.2 PACKED TOWERS

The packed-tower type of scrubber, shown in Figure 14-8, is widely used. The tower contains both a liquid solution and a nonreactive packing (for example, beads) Gas enters through a pipe connection near the bottom and bubbles up through the solution. The packing helps keep the gas stream in bubble form and provides a wetted surface to improve gas/liquid contact as the sample flows in a random and circuitous path through the packing to the top of the scrubber. Liquid carryover, which results from foaming in the scrubber, can be removed by use of downstream baffles or entrainment separators.

14.8.3 GAS LIFT SCRUBBERS

The scrubber depicted in Figure 14-9 is the gas-lift type. The gas sample enters the gas lift and breaks up into bubbles, each lifting a little liquid ahead of it, traveling up the tower. At the top of the tower the gas and liquid separate with the liquid returning to a reservoir to be used again. This scrubber is particularly suited to those applications where considerable precipitates are formed in the scrubber. The gas lift carries the precipitates over into a filter where the solid content is separated from the liquid.

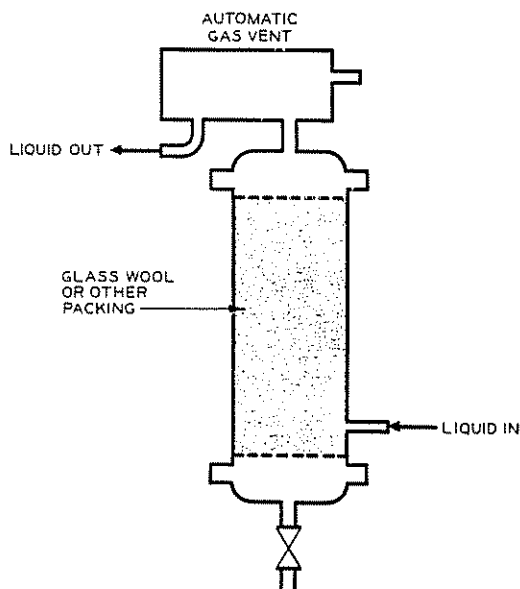


Figure 14-6—Entrained Gas Separator

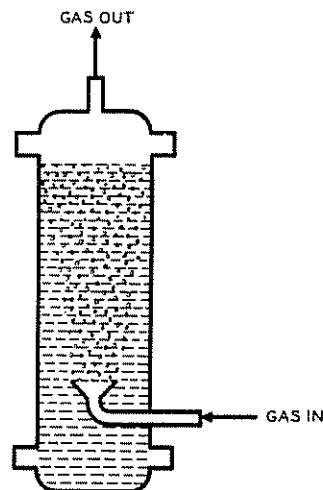


Figure 14-7—Sparger

14.8.4 TREATING SOLUTIONS

Hydrogen sulfide is frequently removed from a gas stream by bubbling it through a caustic soda solution. Moisture can be removed by bubbling the gas stream through concentrated sulfuric acid, provided the acid does not react with other components, such as unsaturates or aromatics, in the sample. It is desirable for scrubbers to be sized to hold from one week's to a month's supply of reagent so chemical changing may be done in a routine but infrequent manner. Specialized solutions may be used where normal treatment does not meet the requirements.

14.8.5 CLEANUP OF TREATED SAMPLES

Entrainment of chemicals may cause false indications or even damage the analyzer. Reaction or scrubber pots for gas streams should be designed using at least one

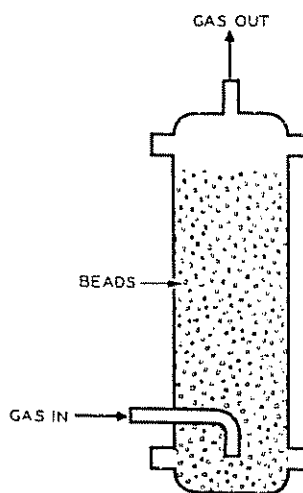


Figure 14-8—Packed Tower Scrubber

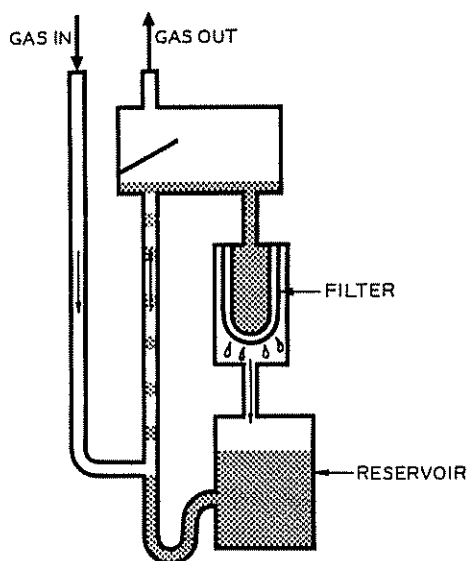


Figure 14-9—Gas Lift Scrubber

and one-half times the cross-sectional area calculated by conventional published design methods. Usually knockout pots should be slightly larger in area to be certain entrainment is eliminated. Knockout pots may have tangential inlets. In sizing pots, the internal volume above the liquid must be considered. Prescribed levels should be clearly indicated for the benefit of maintenance personnel because an overfilled pot may create carryover problems, and a half-empty pot may increase time lag. If an appreciable liquid carryover is expected, both scrubbers and knockout pots may require gage glasses to determine the liquid level.

14.9 Valving

Proper operation and tight seating of valves is important in a sampling system. Small leaks between sample streams or leakage of calibration gases into the sampling system causes erroneous results. Special attention must be given to valve selection for sampling systems. There are several requirements common to all types of valves. Construction materials must resist corrosion by sample components and must not absorb or contaminate these components. There should be as few moving parts as possible, and they should be designed for minimum wear and dependable service without lubrication. There should be no dead space to hold up a portion of sample material and then later release that quantity to contaminate the sample stream or carrier. Leakage must be avoided particularly where the valve is mounted inside housings or in the analyzer enclosure.

14.9.1 BLOCK VALVES [11]

In order to allow the system to be shut down for maintenance, a block valve should be installed im-

mediately downstream of the sample takeoff point, at the inlet and outlet of the analyzer, and in the sample return line. Where reverse flow is possible, provide a check valve in the return line. Block valves should be either gate valves or cocks of the proper material and with suitable packing. The valves at the sample takeoff point and in the sample return line must meet or exceed process line specification. Care must be taken to install the valves in the correct flow direction. This is especially true on systems that run at pressure levels below atmospheric.

14.9.2 SWITCHING

Automatic switching may be accomplished through solenoid valves. These should be installed on the assumption that they will leak and means should be provided to eliminate mixing of materials between two or more lines. Double-block and bleeder valves, properly synchronized, can eliminate this mixing. If several streams are involved, a simpler system uses three-way solenoid valves on each stream with the material being diverted to a vent or drain when not passing to the analyzer.

In some services the use of solenoid-operated valves may not be satisfactory. In these cases the use of piston-, diaphragm-, or motor-operated valves should be considered.

14.9.3 SPECIAL VALVES

For such analyzers as chromatographs, special valves have been developed to deliver small discrete gas or liquid stream samples whose volume or mass² is held constant. By minimizing the sample volume, the analysis time is greatly reduced.

These special valves are commercially available from several manufacturers. Their use on clean streams speeds up analysis and reduces analyzer maintenance since less material passes through the instrument. Where a representative liquid sample can be obtained, liquid sampling valves may be used. These valves may reduce vaporization difficulties. However, the installer should be certain that vaporization will not occur in the sample valve when transferring liquid "slugs." Frequently, it is essential to maintain a back pressure on the sample valve discharge line to keep the pressure of the liquid sample above its bubble point. Special valves associated with particular types of analyzers are included in the discussions of the analyzers covered throughout the text.

² This use of the word *mass* connotes a fixed volume of material in a single phase at fixed pressure and temperature conditions and assumes that successive samples are nearly the same composition.

14.10 Volume-Mass Relationships [11]

Some quantitative measurements are functions of the number of molecules of gas in the analysis cell. In such cases the temperature and pressure of the sample are highly significant to accuracy.

14.10.1 LIQUIDS

For liquids, only the temperature effect need be considered. Most manufacturers of the liquid type of analytical instruments build in temperature compensation where necessary.

With uncompensated instruments, if the temperature coefficient is small (that is less than 1 percent of full scale per degree Celsius) temperature compensation or control is necessary only if the instrument experiences large temperature variations at the analyzer cell. If the temperature coefficient is less than 5 percent per degree Celsius, temperature compensation of the analyzer is usually sufficient. Coefficients larger than this may require temperature compensation and control for both the instrument and sample stream. However, temperature control of the sample can introduce errors in the measurement. For example, heating can cause bubble formation, polymerization, decomposition, or hydrolysis. Therefore, caution must be exercised in such instances.

14.10.2 GASES AND VAPORS

For gases and vapors, the number of molecules per unit volume at constant pressure is inversely proportional to the absolute temperature. For gas analyzers, the measurement may be exponential for changes in the number of molecules in the measuring cell. Two variables, therefore, may affect the measurement when the temperature of the gas in the measuring cell varies. Whether or not the error introduced requires temperature control of the gas in the measuring cell depends upon the required measurement accuracy, the temperature coefficient of the measuring cell, and the temperature variations without control of the gas sample and measuring cell.

The temperature coefficients usually range from approximately 0.2 percent of full scale to several percent per degree Celsius. Gas sample temperatures may fluctuate as much as 50 to 60 degrees. Therefore, in most cases, the gas sample temperature must be controlled in order for an analyzer to be accurate within 1 percent of full scale.

14.10.3 VAPORIZING

Frequently, liquid samples must be analyzed in instruments designed to handle vapor only. In this case, a vaporizer is included as a part of the sample system.

Vaporizing can be a difficult problem, thus vaporizers should be carefully selected. The most popular methods for vaporization are the vaporizing pressure regulator or the capillary-tube vaporizer. Although satisfactory for most clean hydrocarbon streams, both methods are unsatisfactory for other streams because of three phenomena. The first factor is sample fractionation, or separation of sample components in a manner that cannot be predicted or controlled, thus giving a sample which is not representative. The second factor is a change in one or more of the components themselves, an example being polymerization, which makes the sample nonrepresentative and sometimes plugs the apparatus. The third factor is deposition of dissolved solids such as salts, which, although present only in minute quantities, can build up rapidly in continuous operation. These factors must be considered for any liquid sample before the vaporization principle is used. The systems should be designed so that the temperature of the vaporized sample is always maintained above its dewpoint.

14.11 Flow Rate and Control [11]

Sample flow is usually a compromise between several requirements. The maximum flow rate may be determined by the amount of sample which can be drawn from the process by pressure drop available for the design of the high-speed sample loop, by the maximum pressure drop across a vent line where pressurization of the sample in the cell occurs, or by the temperature effects caused by heat or lack of heat. The advantage of a high flow rate is that it minimizes the time lag in the sampling system. However, the design engineer must also keep in mind the capacity of the various sampling system components—filters, scrubbers, separators—that are being provided to prevent or alleviate certain undesirable conditions. At high flow rates, filters may need more frequent cleaning or replacement, and scrubbers will need to be regenerated more often. High flow rates tend to increase the possibility of entrainment whether it be gas bubbles in a liquid stream or liquid droplets in a gas stream. High flow rate sampling systems require higher capacity system components than do low flow rate systems.

Where high flow rates are necessary to minimize time lag and yet a clean sample is required at the analyzer, a bypass loop (see Figure 14-1) may be provided up to the analyzing unit of the instrument at which point only a small portion of the sample need be removed and conditioned for analysis. The bypass flow being high in comparison to the quantity passing through the instrument permits a high sampling rate. However, it is usually unnecessary to condition bypassed material beyond



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With uncompensated instruments, if the temperature coefficient is small (that is less than 1 percent of full scale per degree Celsius) temperature compensation or control is necessary only if the instrument experiences large temperature variations at the analyzer cell. If the temperature coefficient is less than 5 percent per degree Celsius, temperature compensation of the analyzer is usually sufficient. Coefficients larger than this may require temperature compensation and control for both the instrument and sample stream. However, temperature control of the sample can introduce errors in the measurement. For example, heating can cause bubble formation, polymerization, decomposition, or hydrolysis. Therefore, caution must be exercised in such instances.

14.10.2 GASES AND VAPORS

For gases and vapors, the number of molecules per unit volume at constant pressure is inversely proportional to the absolute temperature. For gas analyzers, the measurement may be exponential for changes in the number of molecules in the measuring cell. Two variables, therefore, may affect the measurement when the temperature of the gas in the measuring cell varies. Whether or not the error introduced requires temperature control of the gas in the measuring cell depends upon the required measurement accuracy, the temperature coefficient of the measuring cell, and the temperature variations without control of the gas sample and measuring cell.

The temperature coefficients usually range from approximately 0.2 percent of full scale to several percent per degree Celsius. Gas sample temperatures may fluctuate as much as 50 to 60 degrees. Therefore, in most cases, the gas sample temperature must be controlled in order for an analyzer to be accurate within 1 percent of full scale.

14.10.3 VAPORIZING

Frequently, liquid samples must be analyzed in instruments designed to handle vapor only. In this case, a vaporizer is included as a part of the sample system.

Vaporizing can be a difficult problem, thus vaporizers should be carefully selected. The most popular methods for vaporization are the vaporizing pressure regulator or the capillary-tube vaporizer. Although satisfactory for most clean hydrocarbon streams, both methods are unsatisfactory for other streams because of three phenomena. The first factor is sample fractionation, or separation of sample components in a manner that cannot be predicted or controlled, thus giving a sample which is not representative. The second factor is a change in one or more of the components themselves, an example being polymerization, which makes the sample nonrepresentative and sometimes plugs the apparatus. The third factor is deposition of dissolved solids such as salts, which, although present only in minute quantities, can build up rapidly in continuous operation. These factors must be considered for any liquid sample before the vaporization principle is used. The systems should be designed so that the temperature of the vaporized sample is always maintained above its dewpoint.

14.11 Flow Rate and Control [11]

Sample flow is usually a compromise between several requirements. The maximum flow rate may be determined by the amount of sample which can be drawn from the process by pressure drop available for the design of the high-speed sample loop, by the maximum pressure drop across a vent line where pressurization of the sample in the cell occurs, or by the temperature effects caused by heat or lack of heat. The advantage of a high flow rate is that it minimizes the time lag in the sampling system. However, the design engineer must also keep in mind the capacity of the various sampling system components—filters, scrubbers, separators—that are being provided to prevent or alleviate certain undesirable conditions. At high flow rates, filters may need more frequent cleaning or replacement, and scrubbers will need to be regenerated more often. High flow rates tend to increase the possibility of entrainment whether it be gas bubbles in a liquid stream or liquid droplets in a gas stream. High flow rate sampling systems require higher capacity system components than do low flow rate systems.

Where high flow rates are necessary to minimize time lag and yet a clean sample is required at the analyzer, a bypass loop (see Figure 14-1) may be provided up to the analyzing unit of the instrument at which point only a small portion of the sample need be removed and conditioned for analysis. The bypass flow being high in comparison to the quantity passing through the instrument permits a high sampling rate. However, it is usually unnecessary to condition bypassed material beyond



passing it through a strainer. Several means which have been employed to control sample flow rates are the following:

1. *Needle valve or orifice:* The pressure upstream of a simple needle valve or orifice is regulated and the sample vented to the atmosphere. This method is applicable where precise control is unnecessary. The flow rate may drift over periods of time.

2. *Differential pressure flow controller:* A differential pressure flow controller may be used (many models of which are marketed as purge units). As shown in Figure 14-10, an indicating rotameter is usually provided, but it is not always an integral part of the controller unit. The flow rate to the analyzer is indicated by the rotameter and can be varied by adjusting the needle valve. The relay maintains a constant differential pressure across the needle valve, thus reducing the probability of flow rate drift. This method requires either a constant upstream or constant downstream pressure.

3. *Additional requirements:* Ordinarily, the function of the sample flow control system is to regulate flow rate. However, there are measurement and analysis systems that require additional regulation, such as automatic correction for variations in barometric pressure, gas specific gravity, and so forth.

The sample stream flow control methods discussed heretofore have been primarily for streams in gaseous state; however, most of these methods can be satisfactory for streams in liquid state. Normally, for the analyzers that process the sample stream in liquid state, the sample stream flow rate control method need not be complex. The simple flow control unit shown in Figure 14-11 can be used where there is little change in sample viscosity or density.

A positive displacement pump, driven at fixed speed, is frequently used for controlling flow. The metering pump minimizes the effect of viscosity and density changes experienced in other types of flow controllers, but maintenance requirements often limit its use. A rotary pump delivers a more uniform flow than a piston or diaphragm type. However, the rotary pump must have close clearances to hold delivery constant.

The listing of sample flow control methods could be lengthy. Therefore, each application should be studied

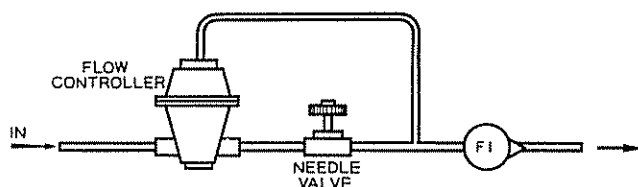


Figure 14-10—Differential Pressure Flow Controller

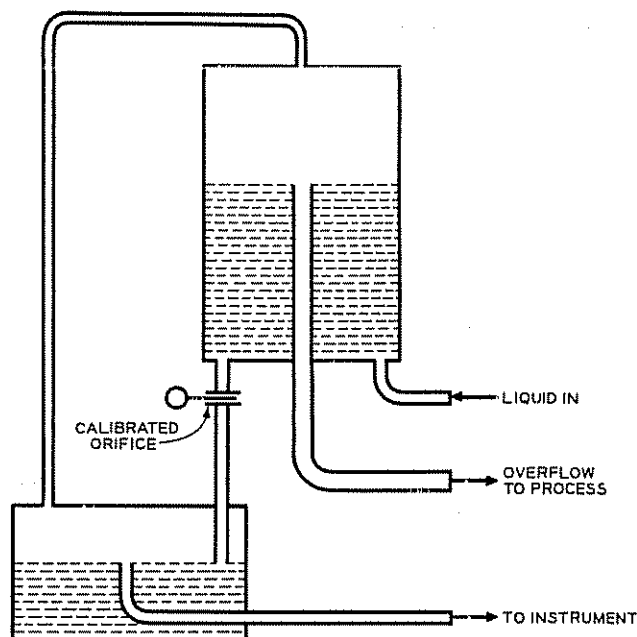


Figure 14-11—Liquid Flow Rate Controller

to determine the minimum acceptable method required to obtain results with the degree of precision desired.

Rotameters are generally used for flow indication. They should be the armored type where required by process conditions.

14.12 Venting [11]

If a separate vent for the analyzer is used, the location of that vent should be in an area of minimum air turbulence. Often it is inadvisable to vent analyzers into a common vent or blowdown system. Frequently, the back pressure in a common system will fluctuate by several inches of mercury. Pressure variations of that order in a sample cell can cause excessive errors in measurement. If it is necessary to vent the gas from the analyzer into a common vent, the sample cell should be operated at an elevated pressure, and a back-pressure regulator should be used. When changes in barometric pressure may cause relatively large errors in measurement, the use of an absolute-pressure regulator may be necessary. Several types of regulators are described in manufacturers' literature. A good back-pressure regulator can hold the upstream pressure constant regardless of variations in barometric pressures. Some are capable of maintaining the set pressure within ± 0.5 inches of water.

Whenever a chance of diffusion from the surroundings into the analysis stream may exist (such as a fire hazard or other unsafe condition), the possibility of back-diffusion from the venting system should not be



overlooked. Maintaining good flowing velocity in the vent system may be helpful in such cases. Use of a properly located back-pressure regulator will assist in this regard.

Consideration should be given to the vent piping design to prevent condensate from accumulating in low points and obstructing a free vent flow. Also, the open end of the vent riser should be designed to prevent the entrance of rain or snow and to minimize the effects of wind impacting on the open end of the vent. A tee with a side port connected to the vent line is an effective discharge arrangement.

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SECTION 15—GAS CHROMATOGRAPHS

15.1 Scope

This section outlines methods for the installation of process analyzers involving the techniques of gas-solid and gas-liquid partition chromatography. Instruments for laboratory use are not covered nor are instruments for high-speed liquid chromatography.

15.2 General

The gas chromatograph is a device which is used for making qualitative and quantitative analyses of selected stream components and for promptly supplying information equivalent to that obtained from a refinery control laboratory. The purpose of the gas chromatograph is to determine quantities of individual components, or combinations of components, to the extent necessary for intelligent operation of a process. It can be used for the following:

- 1 Single key component analysis
- 2 Multicomponent analysis (single stream)
- 3 Complete analysis (single stream)
- 4 Multistream analysis, either partial or complete.

The gas chromatograph is made up of separate elements,¹ each of which has its own operating principles and characteristics and, consequently, its own installation requirements. The combination of elements employed in a particular chromatograph establishes its installation requirements. Because possible combinations are numerous, this section of the manual describes only the more common variations of each element, and enumerates the characteristics and limitations that affect installation of each variation. Total installation requirements for a specific instrument can be determined by adding up the requirements for each of its elements.

A fairly thorough knowledge of gas chromatography is desirable for proper application and installation. The reader is referred to general textbooks for detailed information on gas chromatographic theory and practice and is advised to study the publications of equipment vendors and to consult the indexes of periodicals and technical abstracts for the latest information available.

Although design, procurement, and installation procedures for analyzers are generally the same as those

used for conventional instruments, increasing use is being made of separate analyzer contractors to handle the analyzer portion of larger projects. This technique has the advantage of utilizing an analyzer specialist for this unique requirement.

15.3 Functions

A gas chromatograph employs elements for separating the sample into components and for identifying and measuring those components.

Reduced to simplest terms, the gas chromatograph is a tube (column) packed or coated with a material that exerts different retarding effects on the components of a gas or vapor sample passing through it. Hence, the components of a mixture introduced as a batch at one end of the column and transported through the column by a moving carrier gas will be separated. The components will emerge from the downstream end of the column at different times, but all the molecules of a given component will emerge together within a narrow time span. A sensitive detector is employed at the column outlet in order to reveal the presence and concentration of emerging components. The detector signals may be displayed on a strip chart recorder in the form of deflections (peaks).

Changes in the column packing material and in the temperature at which the column is maintained provide a means for changing the type of separation achieved. Other factors also influence the separation. The gas chromatographic instrument is designed to hold all factors which influence the separation constant, so that repetitive analyses on a given sample will yield identical patterns of peaks (chromatograms). Therefore, with a properly operating process gas chromatograph, any changes in peak sizes or number of peaks observed on successive process samples will reflect changes in the process.

15.4 Chromatograph Requirements

A gas chromatograph may be divided into seven elements each of which performs specific functions

1. A sampling apparatus for injecting a controlled volume of the sample
2. A temperature-controlled chamber housing at least the column and usually the detector

¹ The more common term *components* is avoided in describing the instrument to prevent confusion with sample components and sample system components