SAMPLING SYSTEM GUIDELINES

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Presented at the
19TH ANNUAL
ISA ANALYSIS INSTRUMENTATION SYMPOSIUM
April 24-26, 1973
St. Louis, Missouri

Instrument Society of America
Instrumentation · Systems · Automation
400 Stanwix Street
Pittsburgh, Pa. 15222

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ABSTRACT

This paper covers basic design factors for typical sampling problems. Guidelines are given to provide the instrument engineer with a checklist of items to consider when designing sample handling systems. The guidelines are also useful to aid communication between instrument engineer and process engineer. Data is presented on system time lags and flow rates required for given lag times with various size sample lines. Several examples are given showing proper and improper installations.

INTRODUCTION

Much has been written on the subject of sampling. It's very interesting to read some of the earlier papers and see the progression of sampling ideas and methods. Recently, there have been several excellent papers given that cover specific sampling problems. This paper is intended to give general guidelines for approaching sampling problems.

STATEMENTS AND DEFINITIONS

First, let us cover some basic terms and state the problem a little more clearly. Analyzers and sampling systems are not in themselves important. Analyzers and sampling systems are only tools that make the analysis possible. The analysis cannot be accomplished without both a good analyzer and a good sampling system. The purpose of the sampling system is not to deliver to the analyzer a sample of the exact composition as that in the process line. The purpose is to deliver a representative sample suitable for the analyzer in which the variables to be measured vary according to the stream composition.

The sampling system and the analyzer should be complimentary of each other to accomplish the required analysis and not make impractical demands on either because of poor design in the other. All too often impractical and unnecessary demands are made of on-stream analyzer systems. Don't lower your necessary requirements but, "If you don't need it, don't do it". This is the basic philosophy of design to use throughout the analysis system.

Engineering neglect contributes to the problems of sampling. The specifications for analyzers are generally very detailed but the sampling system frequently receives only a casual mention.

A sampling system doesn't have to be high priced to be good, but it should be adequate to do the required job. This point will be shown throughout the discussion.

The requirements of an on-stream analysis (which involves both the analyzer and the sampling system) is to analyze the process stream:

1. as completely as required,
2. as fast as required,
3. as accurately as required,
4. and present the analysis in a desired and usable form.

Since the analyzer is so closely tied in with the sampling system, the analyzer location is very important. The proper location of the analyzer can sometimes lessen or even eliminate some of the difficult sampling problems and requirements. Some guidelines for locating the analyzer:

1. Locate as near as practical to the sampling point.
2. Locate where it will be convenient for servicing.
3. Locate where the required utilities are available.
4. Do not block accessibility to other equipment.
5. Provide adequate shelter from the elements.
6. Avoid locating in a hazardous working area or near hazardous equipment.

BASIC FUNCTIONS OF A SAMPLING SYSTEM

In view of the previous comments, now let us consider the sampling system portion of the analysis system. There are four basic functions required of the sampling system.

1. Obtain a representative sample from the process.
2. Condition the sample to make it suitable for the analyzer without modifying its basic characteristics.

3. Deliver the sample to the analyzer quickly enough to make the data of value.
4. Accomplish the three functions above without excessive maintenance and attention.

DESIGN FACTORS

When the engineer starts to design a particular sampling system there are many factors to be considered. Some of the basic questions that must be answered are:

1. What is the process stream?
2. What is the condition of the process stream?
3. Where should the sample point be located?
4. What is the sample system dynamic requirement?
5. What will be required to condition the sample?
6. What are the required materials of construction?
7. Where can the sample be disposed of?
8. What are the maintenance considerations?

STREAM IDENTITY

To list the identity and the condition of the major components in the stream is not enough. Just as important is the identity and condition of any contaminates or unwanted components in the stream. The pressure, temperature, and phase must be determined in order to design the best sample conditioning equipment.

SAMPLE POINT LOCATION

The sample point location and the method of sample removal from the process stream is very important from the standpoint of dynamics and other factors in the system. The sampling point should be:

1. Located in the live stream.
2. Located near the point where corrective action is applied to the process.
3. Located as near as practical to the analyzer sampling valve.
4. Located to provide a sample at moderate pressure and temperature.
5. Located where the process reaction or mixing is complete and stable. Avoid locating near the junction of two streams.
6. Located where stratification and poor mixing cannot occur.
7. Do not locate it immediately downstream of a pressure reducing valve where a mixed phase may exist.
8. Located where infiltration of foreign gases or vapors cannot contaminate the sample.

The way in which the sample is removed from the process stream is very important. Never bring the sample off the wall of the process line. The flow rate along the walls of a rough walled pipe is zero or nearly zero. A sample probe should be used which extends to the center of the pipe.

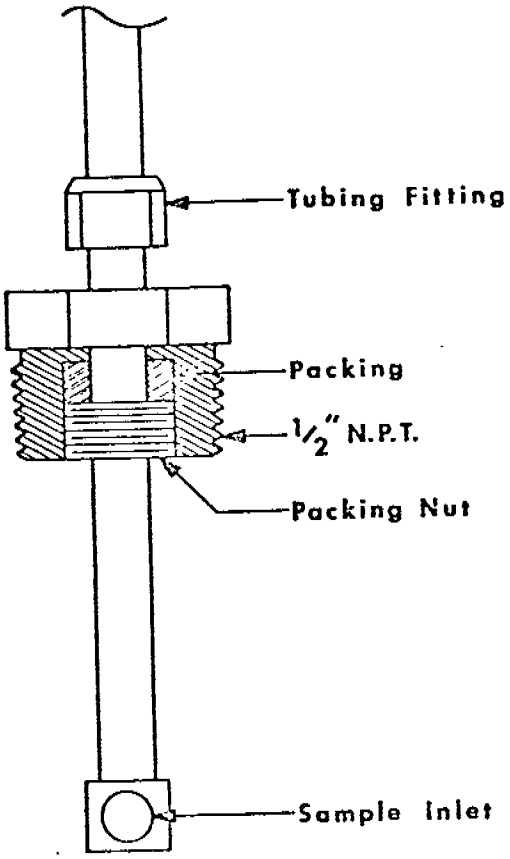
One version of a good sample probe is shown in Figure 1. The probe aids the dynamics of the system, and when the probe is installed in the correct position it will solve some of the other sampling problems associated with removing contaminates. See Figures 2 and 3 for proper installation. By locating the sample probe in a live stream and near the point where corrective action is applied you cut down on the lag time within the process. With the probe extended to the center of a filled line, the freshest sample in the line enters the sample line. Where the process is a reaction or mixing operation, care should be exercised to sample at a point where the reaction is complete or stable and mixing is complete. Stratification will occur in some streams such as hydrocarbons in a long pipe line. Avoid sampling downstream of a pressure reducing device where a mixed phase may exist. Don't locate the sample point near a vent or entrance to a vessel where infiltration of foreign gases or vapors will occur. The fluids will migrate up the walls of the line and contaminate the sample.

DYNAMICS

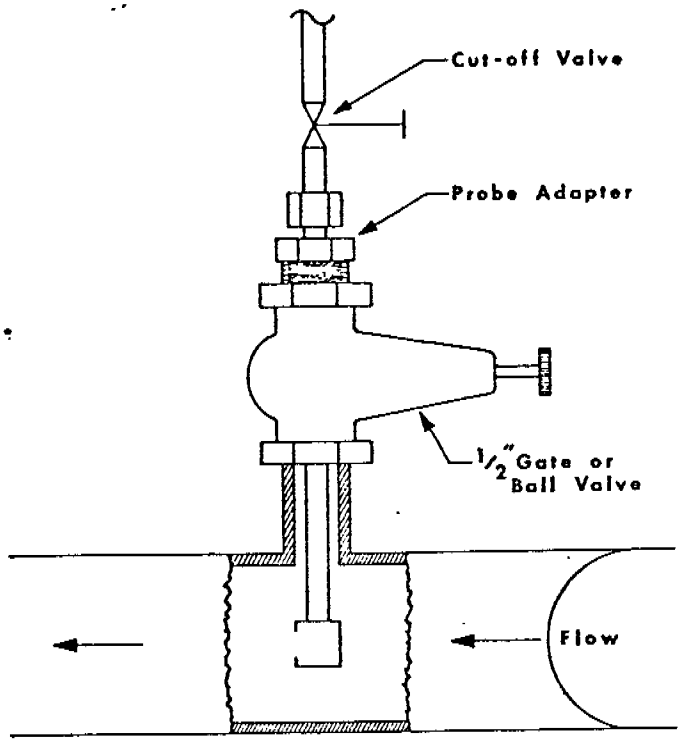
The dynamic requirements of the sampling system are determined by the dynamics of the process and the analysis time required of the analyzer. You can't control a fast process from a slow analysis. You can only see what happened some time ago, although this may still be of some value. For example, if the analysis time is in the order of twenty minutes and the stream is sampled every two hours, the sample system lag time can be several minutes and not hinder the analysis. Using large diameter tubing or pipe (3/8" to 3/4") does not improve the sample lag time over using small tubing for the same distance. With flow measured in feet per second the time is independent of the diameter. Also, with a given fluid it requires a longer time to purge out a large diameter vessel than it does a small diameter vessel. Small diameter, smooth wall tubing should be used as sample lines. We normally use 1/4" OD or 1/8" OD tubing but I know of instances where 1/16" OD tubing has been used successfully. Figure 4 shows internal volumes and flow rates required to purge various common sizes of tubing.

PRESSURE REDUCING

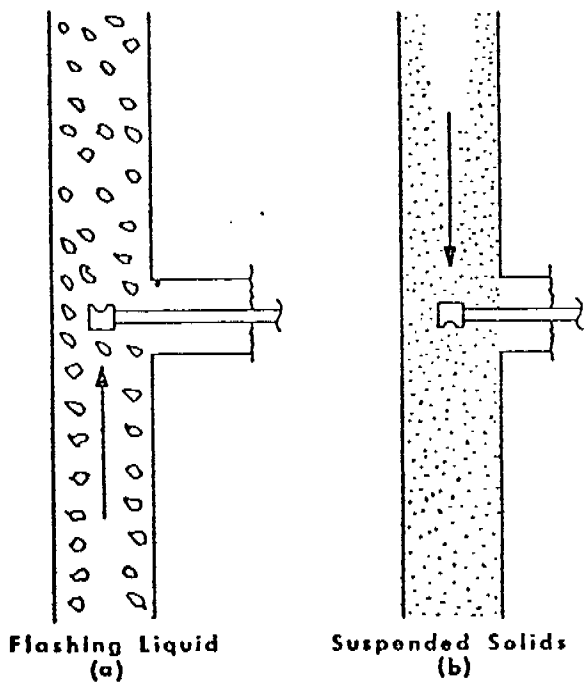
When sampling high pressure gases, the pressure should be reduced as near as possible to the process line, within inches if possible. Where liquids are vaporized and sampled as gases, the vaporizing should be done near the process line or the liquid sample should be circulated and a side stream vaporized near the sample valve. When taking the side stream, you should remember that the expansion factor of most liquids being vaporized is 200:1 to 400:1. It is easy to build more lag time into two to four inches of liquid side stream then there is in all the rest of the system. It is best to sample a liquid stream as a liquid if conditions and equipment allow it, because of the side effects of vaporizing some



SAMPLE PROBE
FIGURE 1



SAMPLE PROBE INSTALLATION
FIGURE 2



SAMPLE PROBES WITH VERTICAL FLOW
FIGURE 3

SAMPLE TUBING, INCHES O.D.	WALL	VOLUME CC/FT	FLOW RATE* CC/MIN	SCFH
1/16	.012	0.2240	22.40	0.0474
1/8	.029	0.6965	69.65	0.1475
1/8	.016	1.342	134.2	0.2842
1/4	.035	5.027	502.7	1.065
3/8	.035	14.43	1443	3.056
1/2	SCH.40	60.09	6009	12.73

* FLOW RATE required to purge 100 feet of tubing in one minute assuming plug flow.

SAMPLE LINE INTERNAL VOLUMES
FIGURE 4

stream mixtures. The sample may fractionate, polymerize, react chemically, or deposit dissolved solids. Any one of these conditions will ruin the sample and possibly the vaporizer performance.

TEMPERATURE CONDITIONING

The temperature of the sample will need to be maintained constant to assure constant sample sizes. For gases the temperature may need to be controlled at some elevated temperature to prevent any possible condensation. Some liquid streams may require cooling to prevent any flashing of the light components, or some heavy liquids may require heating to keep the sample flowing.

FILTERING

If the sample requires filtering, and most streams do, one good type of filter is the porous metal type. There are two types; the "flow through" and the self-cleaning "by-pass" type. The fiber or glass wool type filter may trap oils or other heavies and adversely affect the sample composition. If the process stream is a fluid which contains some bits of solids such as fine particles of pump packing, flakes of rust, etc., these particles must not be allowed to get in the sample valve. They must be separated in some manner from the sample fluid. The "never give it a thought method" is to take the sample off the wall of the pipe where most of the solids are, and filter the sample with a large fiber filter so that the element will last a long time without changing. This solves the solids separation problem, the sample valve works, and the analyzer analyzes. There's only one catch, the analysis is not as good as it should be. If a sample probe is inserted downward from the top side of a horizontal line until the tip is near the center as in Figure 2, and the sample inlet opening is pointing downstream, and the velocity in the sample line is lower than the velocity in the process line, most of the separation is accomplished with the probe. Any remaining back-up filtering can be done with a low volume porous metal filter. By properly locating the sample probe in the process line or vessel the necessity for filtering may be eliminated. A filter may be installed on the end of the sample probe which is inserted into the process line.

MATERIAL OF CONSTRUCTION

The typo of material required for the sample line and the sample wetted parts of the sample conditioning equipment will depend on the chemical and physical properties of the sample, such as chemical corrosion, temperature, and pressure.

SAMPLE DISPOSAL

Sample disposal may be a problem and can be easily overlooked. It is best if the circulating sample can be returned to the process at a point where the pressure is sufficiently lower than the sample point to obtain the required flow. In some cases the sample may require burning, reacting, absorbing or disposal by some other means.

SAMPLE VALVE

There is some question as to whether the sample valve is a part of the analyzer or a part of the sampling system. Either way you refer to it, it is a very important part of the analysis system. The two major types in use today are the "teflon slider" type (linear or rotary), and the "flexible diaphragm" type. Both types have their advantages and disadvantages, which will not be covered in this paper. The valve must give a repeatable size sample and conform to the maintenance requirements covered under maintenance considerations.

MULTISTREAM SWITCHING

There are many special stream switching systems that have been designed and used on different applications. Probably the three most popular types are shown in Figures 5, 6, and 7. They are identified as "Single Block and Purge", "Single Block, Purge, and Bleed", and "Double Block and Bleed" type systems.

In designing or specifying multistream switching systems:

1. Assume that the switching valves will leak.
2. Use separate conditioning equipment for each stream.
3. Watch out for sample contamination.
4. Program to purge the stream to be sampled for the longest possible time.
5. The switching valve should be selected to be chemically inert.
6. The switching valve should conform to the electrical classification code.

MAINTENANCE CONSIDERATION

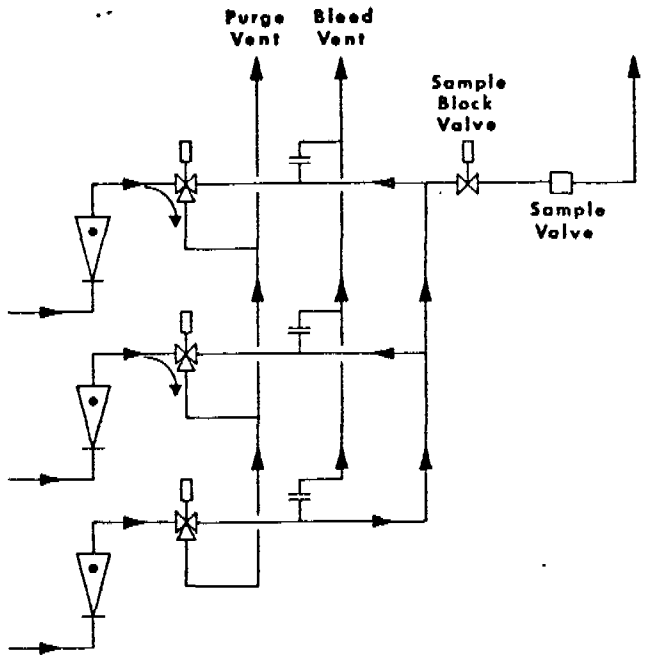
The best possible way to cut maintenance cost on any piece of troublesome equipment is to eliminate that piece of equipment. Don't use the approach, "We want a good analysis so let's put one of everything on it just to be safe". Install only the necessary equipment to perform the required conditioning and only the correct type of that specific equipment. Where troublesome equipment must be used, use a sample by-pass loop and condition only a small amount of the sample. To keep the analysis system on-line most of the time, design and install each piece of equipment in such a manner that:

1. It is readily accessible for maintenance.
2. Any malfunction can be determined and isolated quickly.
3. The malfunctioning part or piece may be replaced easily and quickly.
4. The analyzer recovers quickly from a malfunction.

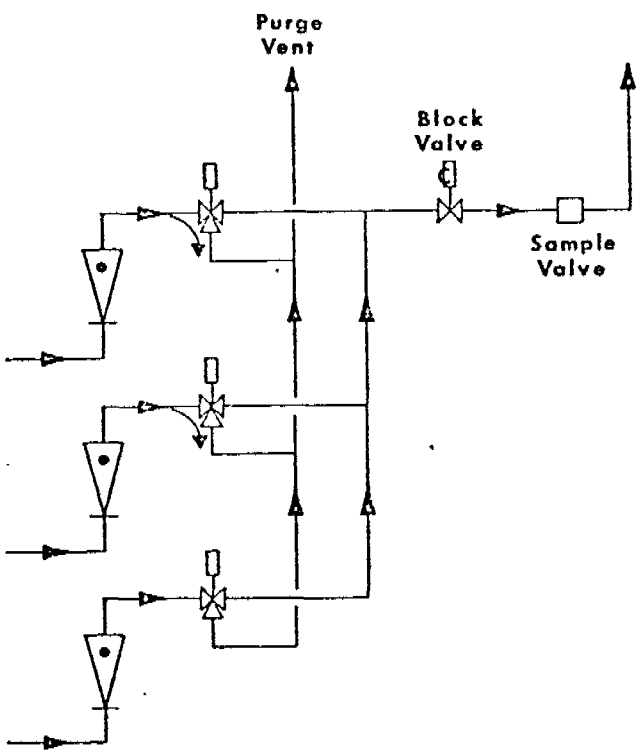
SUMMARY

It is impossible in this paper to cover all the possible problems, designs, and conditioning equipment. A list of sample system guide points are:

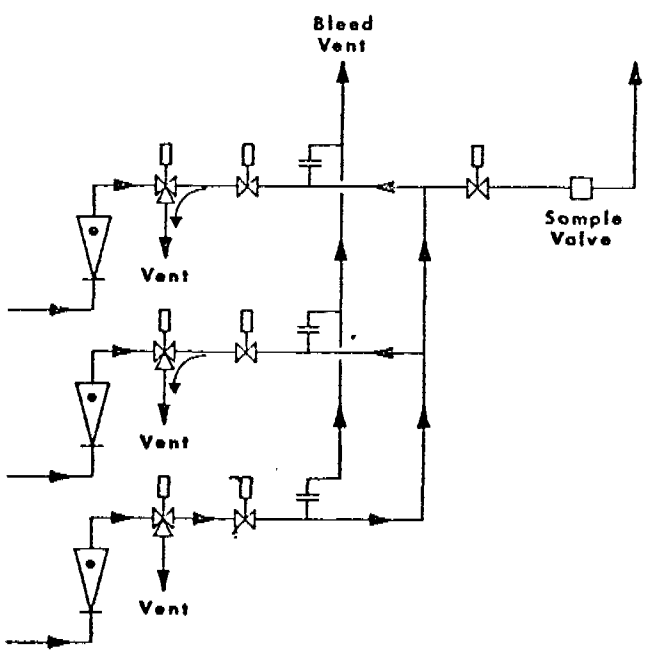
1. Make the sample system as simple as possible.
2. Put in only the necessary equipment.
3. Use a sample probe.
4. Use small diameter, smooth wall tubing for the sample lines.
5. Consider carefully the time lag in the system.
6. Avoid sample pumps if possible. Use a pressure drop across the process system or from the process to atmosphere.
7. Use a sample flow indicator if possible.
8. Do not make traps in the sample lines.
9. Consider the effects of ambient temperature on the sample.
10. Select the sample point to get a live, representative sample and avoid getting contaminates from the stream.
11. Eliminate contaminates that will foul the sample valve such as solids, liquids, gases, and reactive materials.
12. Eliminate contaminates that will foul the chromatograph column such as column poisions, dissolved solids, and heavy liquids.
13. Provide for introducing a standard sample for calibration.



SINGLE BLOCK, PURGE and BLEED
FIGURE 6



SINGLE BLOCK and PURGE
FIGURE 5



DOUBLE BLOCK and BLEED
FIGURE 7

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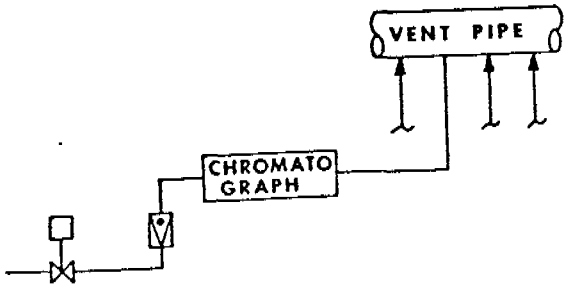
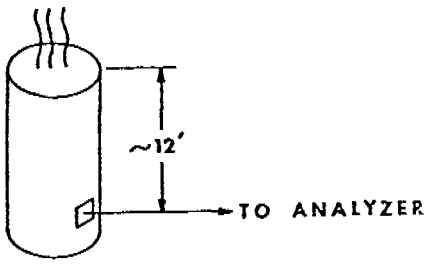


PROCESS
NATURAL GAS RECOVERY

ANALYSIS
SATURATED HYDROCARBONS

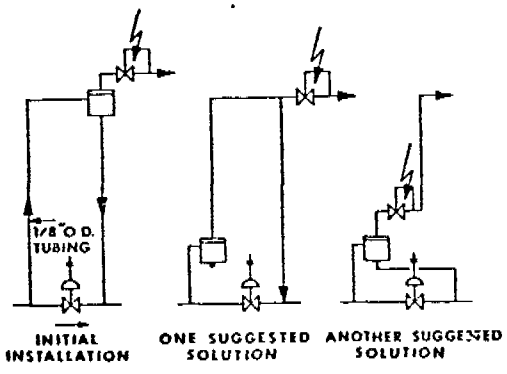
PROBLEM
EXTREMELY ERATIC RESULTS



PROCESS
REACTOR VENT STACK

ANALYSIS
LOW % O_2

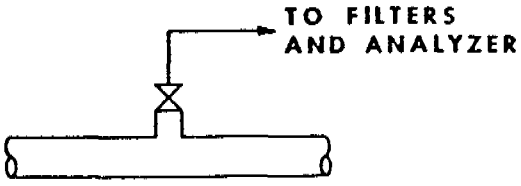
PROBLEM
(1.) ANALYSIS TOO HIGH
(2.) ANALYSIS DOES NOT CORRELATE WITH PROCESS



PROCESS
CAUSTIC SCRUBBER OUTLET

ANALYSIS
PPM CO_2

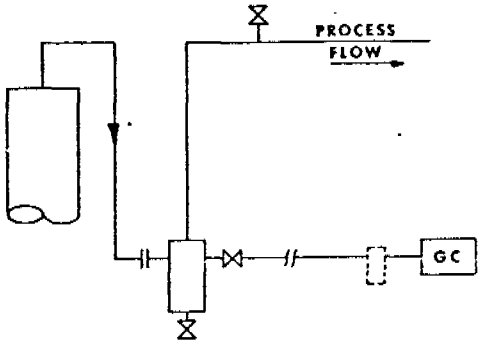
PROBLEM
PLUGGED TUBING FROM "CARRY OVER" CAUSTIC



PROCESS
POLYETHYLENE

ANALYSIS
H_2, iC_4, HEXENE-1

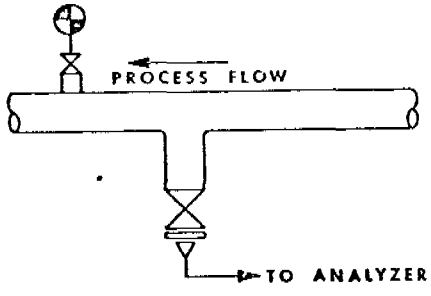
PROBLEM
DAILY CLEANING OF FILTER REQUIRED



PROCESS
AMINE SCRUBBER

ANALYSIS
PPM CO_2

PROBLEM
1. ERATIC RESULTS
2. BLACK "GUNKY" SUBSTANCE FOULS SAMPLE VALVE
3. OPERATORS DON'T TRUST ANALYZER



PROCESS
NATURAL GAS LIQUIDS RECOVERY

ANALYSIS
SATURATED HYDROCARBONS

PROBLEM
FILTER PLUGS FREQUENTLY; ALSO ANALYSIS AND TOWER OPERATION DON'T CORRELATE.

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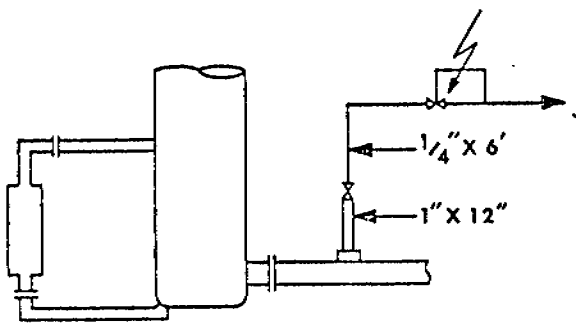
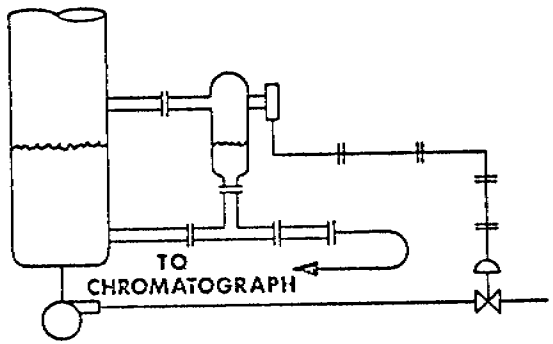


PROCESS
DEMETHANIZER TOWER

ANALYSIS
METHANE

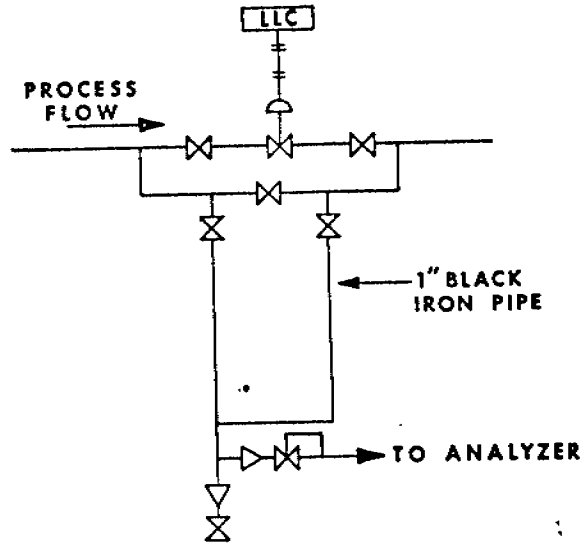
PROBLEM
ANALYSES AND TOWER OPERATION DON'T CORRELATE EVEN THOUGH ANALYSIS CYCLE IS ONLY 30 SECONDS.



PROCESS
CHLORINATED SOLVENTS RECOVERY

ANALYSIS
LIGHT KEY IN BOTTOMS PRODUCT

PROBLEM
ANALYSES AND TOWER OPERATION DON'T CORRELATE.



PROCESS
TYPICAL

ANALYSIS
AS REQUIRED

PROBLEM
CONTROL VALVE OSCILLATES
LONG LAG TIME