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*How to specify and design on line
analyser systems*

by

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HOW TO SPECIFY AND DESIGN ON LINE ANALYSER SYSTEMS

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How to specify and design on-line analyser systems.

On-line analysers are found all through the oil and petrochemical industry. They usually perform well, but on many occasions this was not so from the start. A lot of unnecessary start-up problems are often found with analyser systems. And the result is that maintenance people have the attitude that "analysers never work".

The main source for these problems lies in the specification. This paper deals with a more structured way of writing a specification, what is necessary information and what decision criteria apply.

The best approach is to divide the specification into two phases. Phase 1 is the collection of necessary information, before we can even start to think of an analyser. Here we collect data such as stream compositions, hazardous area information and applicable law's. For this input from all disciplines is required Mechanical engineering should aid in sample tap locations and probe design, Process Engineering defines what analysis is required and whether it is for control or indication only. Instrument Engineering will define what interface-signal must be available. And all groups must review and approve the complete specification.

Only if phase 1 is complete, one can start with phase 2: the actual analyser system specification. If phase 1 is not finalised before phase 2 starts, a small change in basic specification might lead to an enormous change in the analyser system design, with all related costs.

In phase 2 the input from Maintenance is highly favoured. They are experienced in this field and therefor they have there preferences. They can give you the advise you need. And they are the ones that will operate the system you are specifying. So ask them to help you, they can make life very easy for you.

Phase 1: COLLECTION OF NECESSARY INFORMATION.

This is the most important phase in the writing of a specification. This because the information collected in this phase is the basis for all further actions.

What information is needed :

1. Where and what are we going to analyse.
2. What are the stream specifications at the sampling point.
3. What are the piping specifications at the sampling point.
4. What area classification is applicable. Where can an analyser system be located, and which degree of protection is required.
5. How are we going to subtract a sample from the process.
6. What do we do with the analyte. To the flare or back to process.
7. How and what to communicate with the process machines.
8. Which utilities are available.
9. Which regulations standards etc. apply. A system designed according to the Norwegian regulations is not the same as a system designed according to Russian standards !

If this is all known we can make a start with Phase 2 : the specification of the analyser.

Ad 1. Where and what are we going to analyse.

The choice of the sampling point is not always easy. Sometimes process control wants a location where construction has planned something else, or has great objections for financial reasons.

Let us use a fractionator as example. The best way to control the fractionator is to subtract the sample direct at the top of the fractionator and have the sample extracted and vaporised simultaneously, by use of a (steam-) heated sample probe. Construction normally does not like that because of the difficulties and the costs. This leads to the selection of the outlet as take-off position where the sample is subtracted as liquid and only is vaporised in a sample pre-conditioning system.

It is obvious that one needs to know what needs to be analysed. However, please also pay attention to the maximum lag-time that may lay between sample take-off and having the results ready for evaluation, and to the minimum analysis frequency. If you need it only once a day, and time is not important, it is more convenient to have the Laboratory perform the analysis. But a Claus desulphurisation plant performs best if the H_2S/SO_2 ratio is monitored at least each 5 seconds and reported within 30 seconds.

Ad 2. Stream specification.

Before an analyser can be chosen, it is of utmost importance that the stream, which needs to be analysed, is well defined.

This definition of the stream needs to give in depth information not only about the components that can be present in a normal situation but also in not-normal situations (the minimum and maximum concentrations of the components). Besides the concentrations, also physical data such as pressure, temperature, phase, viscosity (at given temperature and pressure), presence of solids etc. is vital.

Most analyser manufacturers do not fully understand the process in which their analysers are hooked-up. The result is that the manufacturer regards the normal stream specification and does not take precautions for process upsets. The upset may easily damage the analyser and the manufacturer hides behind the normal stream specifications with: "you never informed us that such could happen. This is not our problem". And any process engineer knows that upsets happen, and should be able to indicate what the analyser will have to withstand during upset.

Ad 3. What are the piping specifications at the sampling point.

These data are commonly available from the construction engineers.

The specifications are not only for the piping material itself but also for flanges (with their gaskets and stud-bolts), valves etc.

Most often an analyser system designer wants to get rid of piping specifications as soon as possible, and indicate all as being instrumentation.

It is for this reason that a sample line between process and an analyser is commonly 1/4" or 6 mm OD tubing, with compression type fittings. Most piping is welded together and is far thicker. Normally a sample probe is regarded as pipe-spec. and all other is instrumentation.

Ad 4. What area classification is applicable. Where can an analyser system be located, and which degree of protection is required.

The applicable area classification is an important selection criteria for an analyser. Ex or non-Ex, that is the question.

Since each analyser has a certain need for maintenance it is very convenient if the analyser can be located in an general purpose area. We do realise that such is normally not always possible, but still.

Where do we place the analyser, and how many space is available and how should the analyser be protected.

This calls for many variations. Indoors, outdoors under a shelter or out in the open. Please remember that the climate in the Gulf of Mexico is not the same as in the North sea.

It would be very convenient to locate all analysers in one place, the analyser shelter. This enables ease of maintenance, easy climate control for all analysers and if designed well it can create a safe zone inside a Ex-classified area. Nowadays most analyser shelters are fabricated as pre-packaged units which will be fully tested etc. with the supplier before it is installed. Such a transportable shelter can be made of Steel, Glass-Reinforced Polyester or Concrete. All have there own (dis-) advantages. Hardly anyone will use concrete for Off-Shore applications but On-Shore it is great material.

If analysers cannot be grouped together, each analyser (or group of analysers) many are

placed inside a cabinet. Normally an IP 54 cabinet will do but analyser systems which are to placed fully in the open mostly require IP 65 . For this the choice is normally between GRP and Steel.

Ad 5. How are we going to subtract a sample from the process.

The answers to the following questions in fact define the sample probe.

- Will it be a heated probe?
- Is there a requirement for mounting and dismantling the probe under full line-pressure.
- What kind and how many valves are required?
- Is pressure reduction necessary? Or is a Pitot-probe to help build up pre-pressure required.
- Which process connections will be available.

Ad 6. What do we do with the analyte.

In former days it was quite common that the analyte was vented or send down the drain. This was also true for fast-loops. However, if compared on a yearly basis a lot of money was send down the drain too. Furthermore, venting/draining mostly is bad for the environment and flare systems do cost money.

With above in mind it is clear common sense that good sample return location is found. It makes life of environmentalists easier and it saves money.

If the analyte can be returned to the process, the process conditions at the return point must be made available. There have been situations that the return point was badly specified and that after installation it was found that the return pressure was far higher than take-off pressure. Only the installation of an expensive pump could solve this problem.

Ad 7. How and what to communicate with the process machines.

Or rephrased : will a simple 4...20 mA signal do or is better communication called for.

First of all specify the process machines that will be used. Many analyser manufacturers, and especially the gaschromatograph manufacturers have added networking capabilities to their machines. This may even go up to full computer communications protocols like Modbus, completely tested with TDC 3000 machines or equal.

Also RS 485 communication is coming available rapidly.

The best approach is to specify several levels of communication. The question : does your thermo element need a local signal transmitter or is this part of control room instrumentation, can easily change an analyser system.

Ad 8. Which utilities are available.

The utilities are normally poorly specified.

Yes, there is 230 V +/- 10%, 50 (48...52) or 60 (57...63) Hz. For heavy analyser pumps 440 V or 660 V with the same frequency, can be used. And yes, instrument air and steam for heating purposed is available.

But the analyser manufacturer wants to know more.

Instrument air must be dust and oil-free with a moisture dewpoint of at least -20 degrees C. Hydrocarbon dew point at least -40 degrees C. Is there also unlimited supply?? There are certain gas-chromatographs which can consume up to 2,6 m³ per hour!!!

For steam on likes to know whether it is low, medium or high pressure steam and what is the temperature.

Also for other available utilities (like Nitrogen or Hydrogen) data on purity, pressure, availability etc. are required.

And finally specify the available flare system, vent headers (atmospheric?), drain system (closed or open) and or open sewer header. What can go where and what connections, like relief valves, check valves etc., are required.

Sometimes it is good to have a sample recovery system. This can be used for both gas or liquid samples.

Phase 2: THE SPECIFICATION OF THE ANALYSER

The purpose of this phase is to describe the analyser in such a way that both engineering and manufacturer know exact what needs to be delivered (and also what needs not delivered). If this description is done right, it is easy for Procurement to select the right manufacturer. Also it will prohibit that during manufacturing there is a great need for changes or amendments to the system. And if a change is necessary, it is easily defined what is additional work and not.

First thing that needs to be done, is to organise all information as collected in Phase 1. There is data which will be applicable to all analysers, and there is analyser specific information.

If all the analyser specific information is brought together, one can get the idea of which type of analyser will be possible for this particulate application. It is normally easier to analyse oxygen in a range between 5 and 100 % with a thermomagnetic oxygen analyser than with a gaschromatograph.

As soon as a certain type of analyser has been chosen, one can start with the design of the sampling system.

The sampling system can be divided into 5 parts, all equally important, but sometimes not so clear to identify. If a analyser system can be located near the process pipe one might only find a sample probe, some tubing and a cabinet which holds both the sample conditioning system and the analyser, and the 5 individual parts are not easily recognised anymore. However, they are still valid.

Part 1 is the sample take-off and the sample return probe. The sample pre-conditioning (SPCS) system is the second part. This SPCS is to be located as close to the sample take off probe as possible. Its main purpose is to pre-treat the sample in such a way that a fast transport to the analyser is possible. Therefore a SPCS can consist of a filter and a pressure reducer or a pump. If the sample taken is in the liquid phase, one even might vaporise the sample in the SPCS.

The SPCS is followed by the sample transportation system (part 3) and the sample conditioning system (part 4). And last but not least we come to the analyser itself (part 5).

Part 1. The sample probe.

A sample probe serves only one goal: to subtract a representative sample from the process.

And the difficulties mostly arise from the question what is representative. The answer is different from take-off location to take-off location.

The design of the sample probe is mainly dictated by the analyser and the required lag-time. The probe for an oil density analyser is not the same as for gas density.

The design starts with the definition of where to subtract the sample. In a process pipe, from a vessel etc.

For process pipe which run horizontal, it is common that the sample is extracted from the top. The insertion length is chosen such that the probe extracts normally from the middle part between $1/3$ and $2/3$ of the pipe. If a multiphase medium is flowing through the pipe, the length may vary according to the required phase that needs to be analysed. With multiphase media one must consider the use of an in-line static mixer before sample take off. Modern static-mixers have already a side port available for sample take-off purposes.

If the medium is gas, showing full turbulent flow, the sample probe may be very short. One has only to cover for the flow effects near the wall of the pipe, in order to subtract a representative sample.

Subtraction from a vertical process pipe is mm. the same as for horizontal pipes. Please be aware that if high amounts of solids are combined with a vertical downgoing stream, special shields must be used to protect that high amounts of solids are sucked into the probe.

For vessels etc. the probe length is mainly defined by common sense.

A probe strength calculation is mandatory for the proper design of a probe. Many analyser system manufacturers can help you with this, but if you want to be independent, a good approach is to use the same equations as used for thermowells.

A special type of probe is the Pitot probe. This probe can be used to create the necessary differential pressure in order to feed the analyser with sample.

The Pitot probe is in fact a Pitot tube as used in former days for flow measurement, but now the static pressure is used for creating a positive pressure for the analyser. The Pitot-probe can be combined with a reverse Pitot return probe, in order to create an even greater differential pressure.

Special attention must be paid to probes which need to be retracted and installed under full line pressure. If such can be avoided by selecting a different take-off location, please do so. Retractable probes are always much more expensive than normal probes, and they can create great problems if there is a slight bend of the probe.

For special applications, very special types of probes have been developed. ISO kinetic probes, Pyrolysis probes and many others. These will not be discussed here.

Part 2. The sample pre-conditioning system (SPCS).

A sample pre-conditioning system is nothing more than a device that enables a safe fast and easy transport from the sample to the analyser.

For high pressure process lines, the SPCS reduces the pressure to a more moderate pressure, such enabling a short lag time. Consider a sample transport line 6 mmOD, 4mmID with a length of 10 meters. Its internal volume is 0,125 liter. If gas is transported with a pressure of 100 Bar or with 5 Bar the actual content differs 20-fold. Since the analyser analyses normally under almost atmospheric conditions the lag-time for the 100 Bar application is far higher.

Liquid sample transport is often time consuming if compared to gaseous samples. This for very obvious reasons. Some analysers (gaschromatographs) vaporise the sample before it is analysed. Why not vaporise the sample near the take-off probe and enable short lag-times.

Other devices available for SPCS are sample pumps when pressure, filters etc. Attached you will find some schematic arrangements. Diagram 1 and 2.

Part 3. Sample transport.

Sample transport looks so simple but in reality there are many mistakes made.

The problem comes from the fact that sample as leaving the SPCS may not be influenced anymore. If a vaporised liquid is transported, a too low temperature in the transport system will have the high boiling components condensate again.

A sample transport line has a great influence on the lag-time. Therefore a lag-time calculation must be made in order to use the best possible transportation system. Many manufacturers calculate such with own developed Lotus macro's and can help you with this. The actual

expected distance between the SPCS and the analyser is needed for such. So please use Manhattan distances!!

Part 4. The sample conditioning system.

The sample conditioning system (SCS) is used for treatment of the sample in such a way that the analyser can handle it. This means that flow is regulated, relief valves are placed and that filters/coalescers can be present. Also it is there to enable easy calibration of the analyser.

Before a flow regulator is specified, one must be aware of the product and of the onsets that might happen, if anything fails. A good rule is to use metal tube flow regulators if the product is flammable or a pressure above 7 Barg might occur. In all other cases one may evaluate glass or equal materials.

If a coalescer filter is required, the condensate drain must be specified as well. Will it be an open sewer, a closed drain system or is a sample recovery system necessary.

Modern analysers have options available for stream selection, event steering etc. and so a completely automated system can be created. But is this always necessary? In diagram 3 you will see the set-up of a simple sample conditioning system, while diagram 4 show a far more complex type.

Whatever you specify, please keep it simple. Maintenance on complex systems is usually also complex. And it can create many mistakes. Furthermore, pay attention to the cabinet in which the system has to be placed. See to it that not too many items are stuffed in a too small cabinet.

Part 4. The sample conditioning system continued.

And what will happen if we open the cabinet door in winter-time? How long will it take to regain its normal operational temperature? So a heating system has not only to overcome the normal heat-loss but must also have some "spare" capacity.

Part 5. The analyser.

This is the core of the system. And the specification is very simple once we have come this far.

We now know what type of analyser we would like to have, and all related items are specified. Now we need to establish a preference list of make and model of analyser suitable for the Job. With this list and the specification one can ask several analyser manufacturers/suppliers to indicate a budget price for the complete system and to send a good analyser specification.

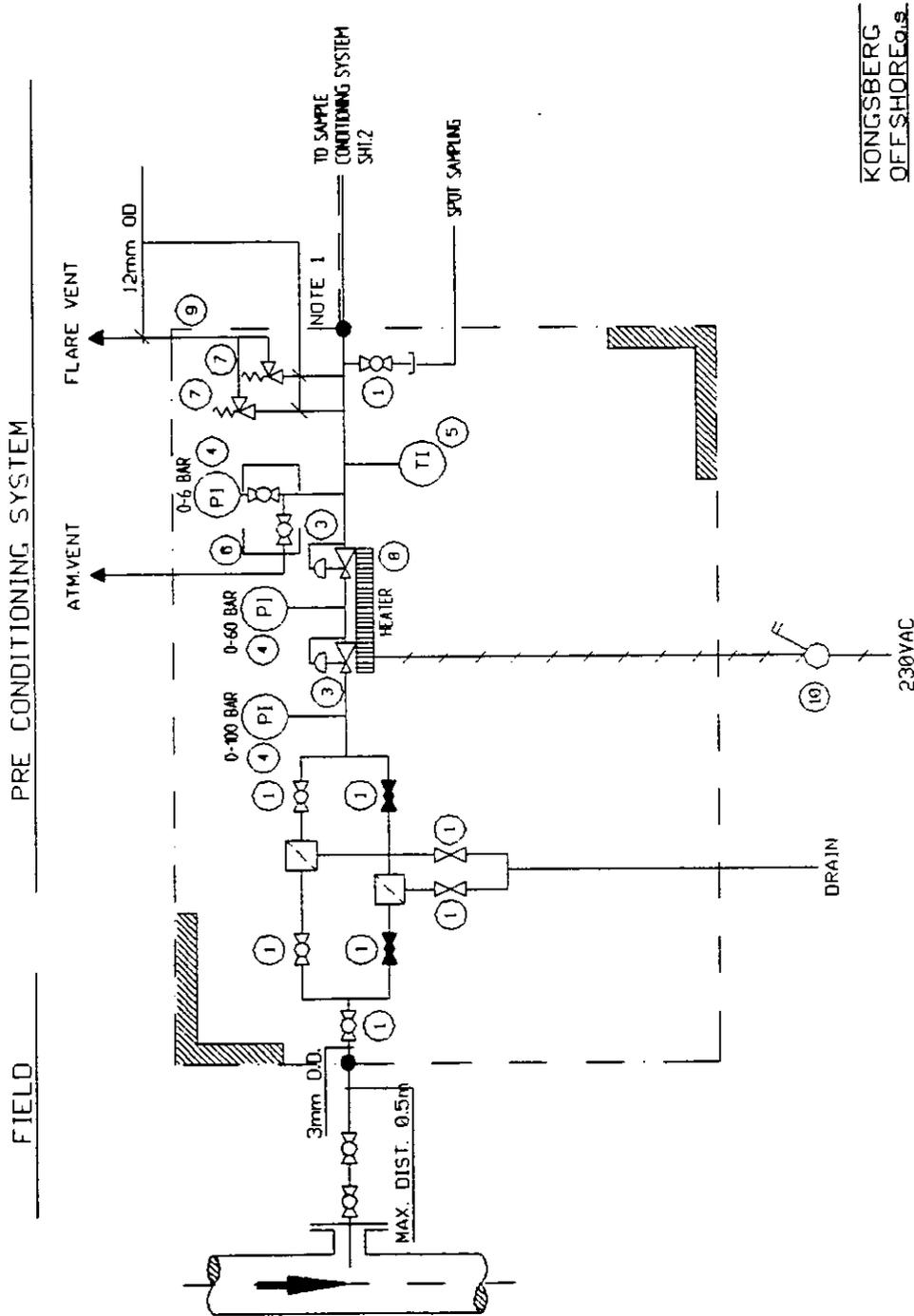
Many analyser manufacturers have what they call "Lock-out" specifications for their analysers. If you use these you make life more difficult for their competitors. So we use 2 or 3 Lock-out specs and we create one general spec, which give good coverage for the analyser and fulfils all of the project needs.

Now the specification is complete, the best we can do is to have it checked by someone not involved in the project. This person(s) can easily indicate whether all information is available, if it is understandable and if it is a realistic design. Let us hope it is, because that was what it was meant to be.

And second last step is having the complete specification approved by the different parties involved. These parties are Process, Mechanical, Instrumentation and Maintenance.

The specification itself is finalised when it is accepted by Procurement. They have to use your specification in their process of selecting the right manufacturer and bying the equipment for the right price. But your responsibility only ends after the analyser system is installed and is accepted by Maintenance as a "working" system.

Diagram 1. Schematic sample pre-conditioning system with dual filter system and dual heated pressure reducing system.



The dual filter system is often used if high amounts of solids are expected, or if the analyser system is of major importance.

Diagram 2. Schematic sample pre-conditioning system with fastloop and sample pump.

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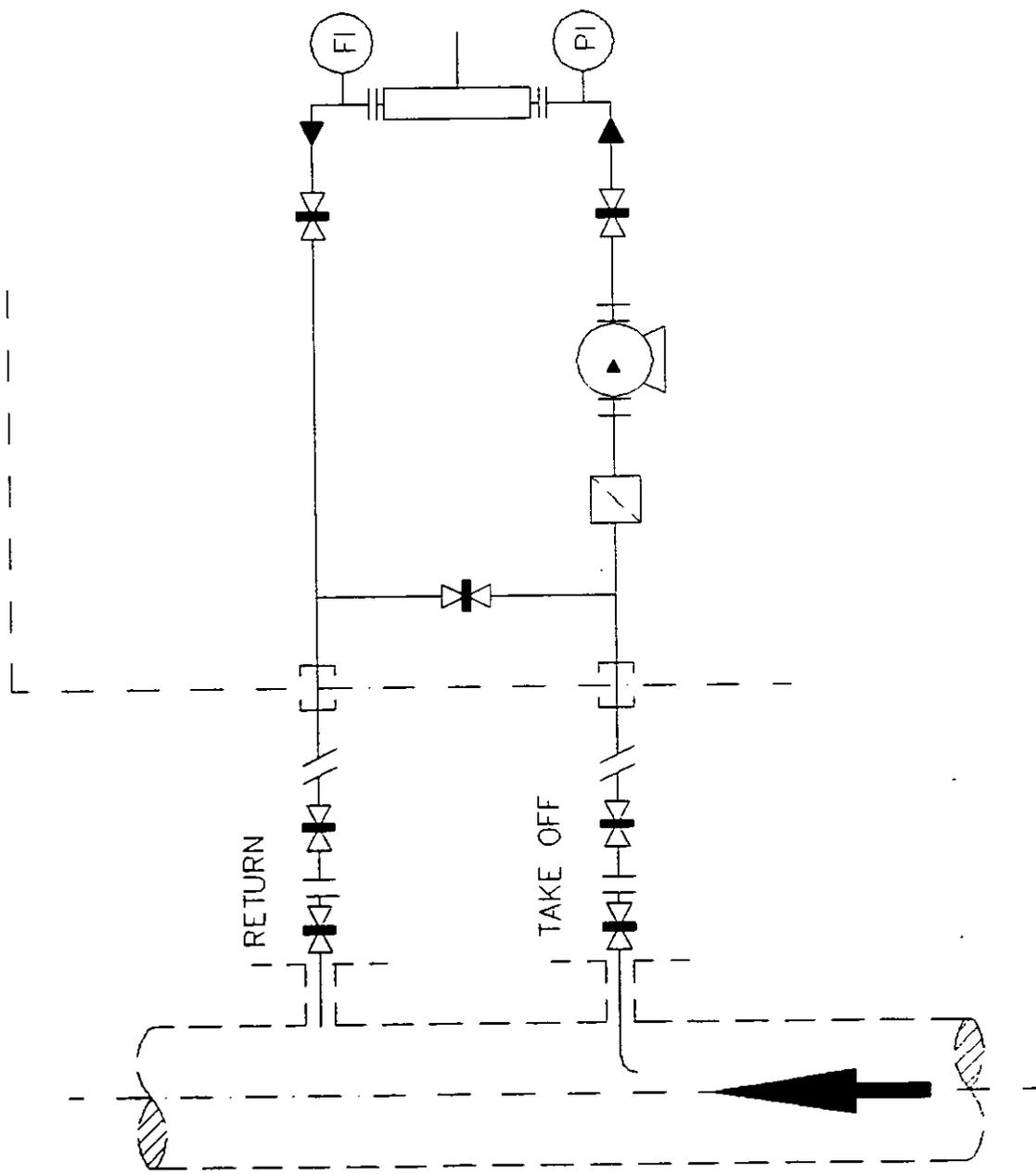
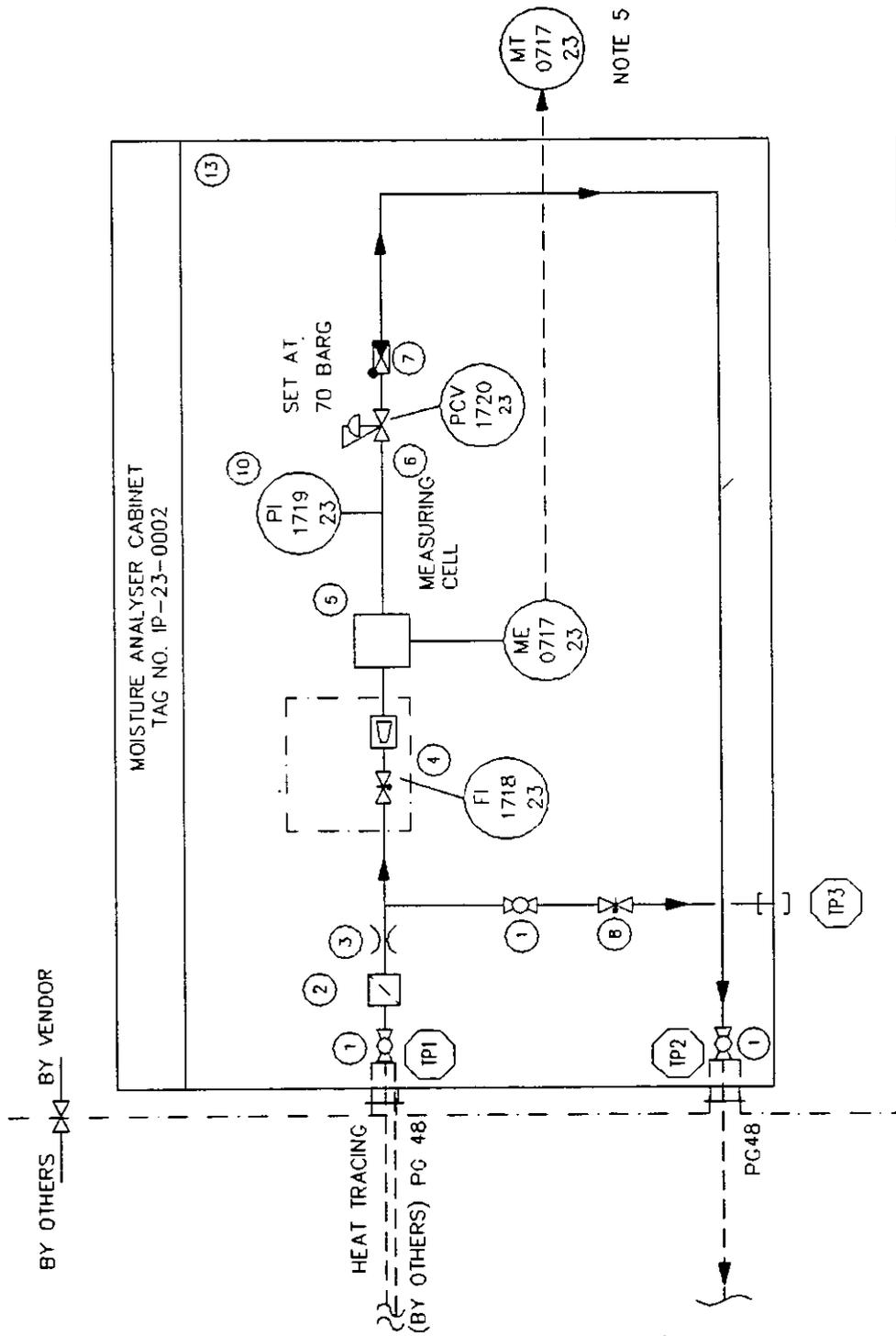
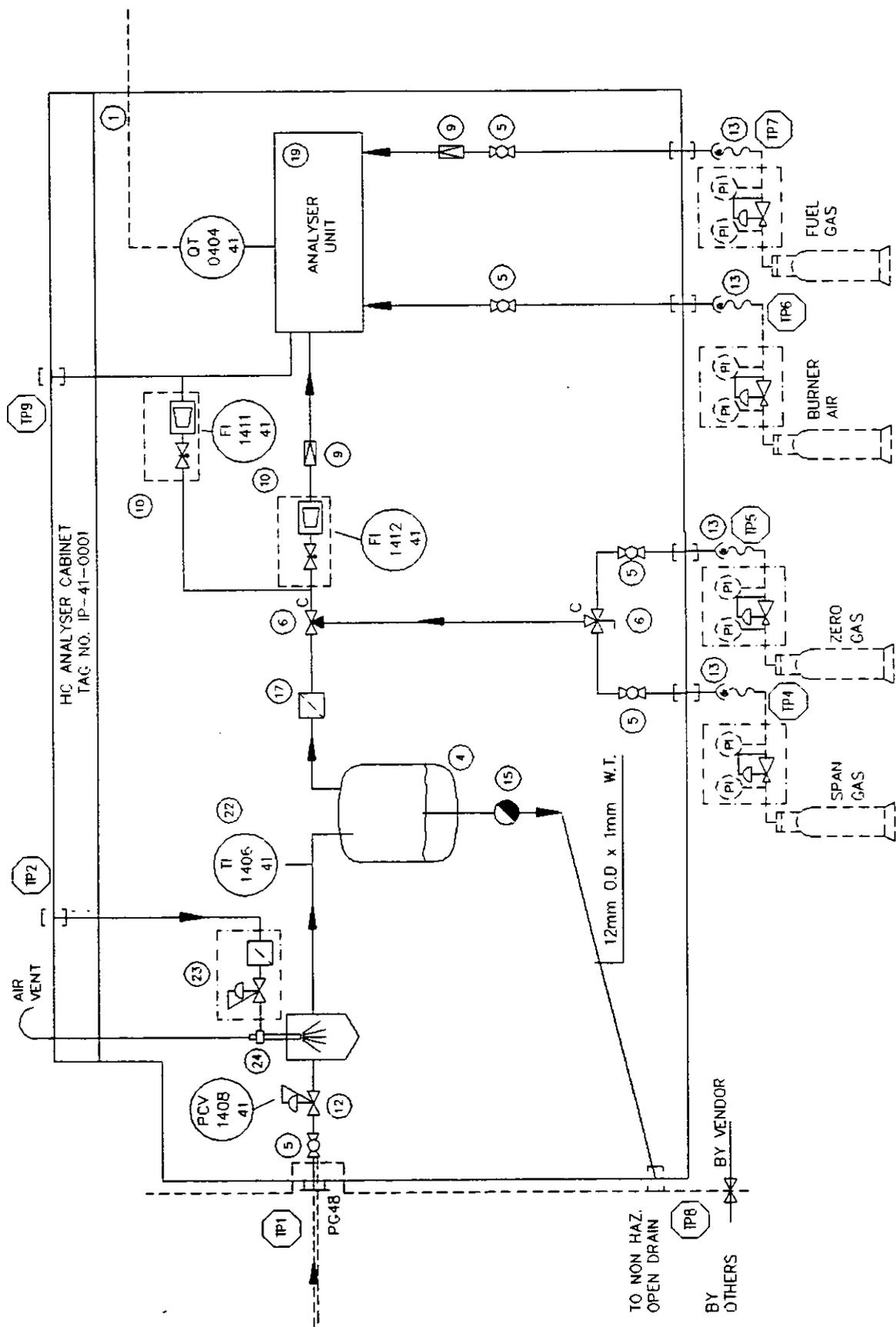


Diagram 3. Sample conditioning system simple.



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Diagram 4. A rather complex sample system



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References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.