

NORTH SEA FLOW METERING WORKSHOP
ARRANGED BY: NORWEGIAN SOCIETY OF CHARTERED
ENGINEERS:

FIELD EXPERIENCE IN
MEASURING WATER DEWPOINT
OF NATURAL GAS

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INTRODUCTION

The determination of water vapor content in natural gas is of major importance to the natural gas transmission industry. If water condensation occurs in a transmission line, many operational problems can be expected. Free water can be sufficient to give;

- * Hydrates - with partial or complete plugging of the pipeline, valves and regulators.
- * Internal Corrosion - with metal loss of the pipewall, corrosion leak and breaks.
- * Compressor faults.

The gas contract between the supplier and distributor usually specifies the maximum allowable water vapor content or water dewpoint. In order to determine if the gas meets the contract specification and to control the operation of the dehydration plant, a precise method of measuring the water content, therefore, is required. Several methods are available, but it has been found that special problems occur when measuring the dewpoint of the natural gas for the following reasons:

- * Natural gas may contain hydrocarbons with a higher dewpoint than water.
- * Natural gas may contain corrosive gases (CO_2 , H_2S).
- * Natural gas may contain alcohols such as glycol and methanol.
- * Natural gas may contain deposits.
- * Calibration on site is difficult.

The following discussion will cover typical methods used for determining the water vapour content of natural gas. Basic principals for a proper installation design will also be discussed and at last Elf Aquitaine NorgeA/S experience on Frigg.

CURRENT METHODS

There are many methods for the determination of water vapour, but only a few are applicable for use in natural gas. Some of these are suitable for a continuous monitoring of water vapour while some can be used only for spot checks. Some of the more important methods is based on one of the following methods.

1. **DEWPOINT.** Gas at known pressure is passed over a cooled mirror. The water dewpoint is recorded as the temperature at which water droplets is first seen to appear on the mirror. If the hydrocarbone dewpoint is higher than the water dewpoint or the gas contains glycols or amines, a great deal of difficulty may arise in the interpretation of the water dewpoint.
2. **ELECTROLYTIC.** Absorption of water by phosphorous pentoxide and electrolysis of the water. The cell of the instrument is an insulating tube with a pair of wires wond in a spiral throughout the inside diameter. A thin film of phosphorous pentoxide is applied between the wires. As the sample passes through the cell the water is adsorbed by the phosphorous pentoxide. A voltage is applied across the two wires which causes the decomposition of water into hydrogen and oxygen. The resultant current that flows follows Faraday's law and is propotional to the number of water molecules electrolyzed. At a constant sample flow the current is a measure of the water vapour in the gas. Methanol and other lower alcohols cause high readings. This method is also flow dependent.
3. **CAPACITANCE.** The capacitance hygrometer is a method for determing the water vapour content of natural gas by using an aluminium strip which has an anodized surface of aluminium oxide. The aluminium oxide is coated with a thin layer of gold. The aluminium base and the gold layer form two electrodes of an aluminium oxide capacitor. Water vapour is adsorbed through the gold layer onto the aluminium oxide layer. The rate of absorption is directly proportional to the water vapour pressure of natural gas. The electrical capacitance of the sensing probe is then converted electronically into a correspondingdewpointtemperature.

This type of instruments are available both as continuous and as a portable instrument.

Solids particles and liquids i.e. glycols can block the sensor pores and reduce the sensitivity of the sensor or give false readings.

4. VIBRATING CRYSTAL. The vibrating crystal analyser measures the moisture in gas by monitoring the vibrational frequency change of a hygroscopically coated quartz crystal that is exposed alternately to wet and dry gas. Sample gas is divided into two streams, sample and reference gas, which are alternately passed through the measuring cell. Before reaching the crystal, the reference gas is passed through a molecular sieve dryer, which removes virtually all of its moisture. As the sample gas is passed over the measuring crystal, moisture is absorbed by the crystal's hygroscopic coating, thereby causing a vibrational frequency change. The frequency difference between the sample gas and the reference gas is proportional to the amount of moisture absorbed from the sample gas. Glycol may interfere the measurement.
5. CONDUCTIVITY. This method utilize the increase in the electrical conductivity of glycerol according to the concentration of water. A pressure test chamber is equipped with a cell consisting of two thin horizontal layers of stainless steel separated by an isolating ceramic material. The eight pocket holes of the cell are half filled with conductive glycerol and behave as independent electronic pairs. Water vapour is absorbed into the hygroscopic glycerol. This effect changes the conductivity of the cell. The cell temperature must be maintained at a constant level. This method responds to relative humidity and the probe is exposed to gas at operating pressure. Temperature variations of the fluid at the sensor can give false readings.
6. CHEMICAL TITRATION - Coulometric titration. Natural gas is bubbled through a Karl Fisher reagent, an iodine based chemical, at controlled flow rate. The water vapour reacts with the reagent and neutralizes it. When the reagent has completely reacted, the time required to reach the end point is electronically transformed into an equivalent water vapour content.

Volumetric titration. Natural gas is bubbled through a methanol or glycol solution at a controlled flowrate. The water is absorbed by the hygroscopic solution. Karl Fisher reagent reacts mole per mole with water and an equivalent amount of water vapor content can be calculated.

The Karl Fisher titration method is both available in a portable and automatic version (1). The portable version is not Ex-proof.

The Karl Fisher reagent undergoes a specific reaction with water. The reagent is inert to hydrocarbons, carbon dioxide, glycols and amines. Hydrogen sulfide and mercaptans react with it and the method is not applicable to gas when the concentration of these components is above about five grams per 10⁶ cubic meter (1). The method is flow dependent.

CALIBRATION OF HYGROMETERS

Calibration of hygrometers is normally done by one of the following procedures:

1. The water content of the gas as read by hygrometer is compared to the readings of another instrument or method known to be accurate (calibration instrument).
2. A stream of gas having a known water content (reference gas) is passed through the hygrometer.

For each procedure several methods are available.

Calibration Instruments

1. Gravimetric - The weight of water absorbed by a drying agent from a known volume of gas is determined. This is a primary laboratory method.
2. Titrimetric - The Karl Fischer procedure is a primary laboratory method.

3. Dewpoint - Measuring the water dewpoint with a manual mirror type analyser is a primary method.

Reference Gas

1. Hydrogen-Oxygen Mixture - A known concentration of hydrogen is combined with oxygen by a catalyst to produce a known concentration of water in a gas stream. A variation of this is to electrolyze water to form hydrogen at a known rate by Faraday's Law, then recombine the hydrogen with oxygen over a catalyst.
2. Permeation Tubes - Water vapour passes at a known rate through the wall of a plastic tube into a dry gas stream.
3. Dilution of Water Saturated Gas - A stream of gas saturated with water at a known temperature and pressure is diluted by a known proportion of dry gas.
4. Standard Moisture Mixture - Compressed gas containing a known concentration of water vapor is stored in a specially coated aluminium cylinder (1).
5. Temperature filter. A stream of gas is passed through a temperature filter. The temperature in the filter will represent the saturation temperature or water dewpoint at the existing pressure.

HYGROMETER INSTALLATION

In order to make a correct determination of water vapour content of natural gas it is important when designing a hygrometer installation to be aware of the effects which may give erroneous reading. The prime requisite for a correct reading is that no opportunity must be allowed for condensation, absorption or adsorption of water vapour. This requires keeping all parts of the sampling system well above the water dewpoint, selecting proper materials when designing the sampling system and very often maintain a constant purge flow. The temperature stability of the sampler system components is also very important. At a given equilibrium condition of temperature the system will absorb a special

amount of moisture. If glycol or another hygroscopic liquid is present in the gas and the sampling system is contaminated, the amount of moisture absorbed is increased dramatically. Any factor which upsets this equilibrium, whether it is a change in the sample concentration or a change in ambient temperatures, will require a new equilibrium condition to be established before a true humidity can be measured. Changes in sample line temperature should be avoided. It is also desirable to locate the sampling system and the hygrometer sensor as close as possible to the pipeline. This is of special importance when glycol is present. Any glycol which is accumulated in the sampling system will increase the response time and may also give false readings. Installation of filters or coalescer upstream the hygrometer sensor in order to protect the sensor must be avoided because this will cause an accumulation of glycol giving the above mentioned effects. Removal of most of the liquid carried over into the sample stream may be obtained by use of a small separator 0,5 - 1 cm³ (filter house with the filter removed) and with a continuous drain of liquid. Installation of a proper sample probe will also reduce the effect of liquid deposits. Outside turbulent area like tees and bends, the liquid contamination will travel along the pipewall and will not be pushed into the sample loop if a sample probe is installed (Fig.1). Further on, it is important to know that a pressure regulator which have to reduce the gas pressure by 150 BAR, will cause a Joule-Thomson cooling of the gas of about 35 - 40°C and therefore if used, the regulator should be heated.

Considering the above mentioned aspect the following design criteria should be followed.

- * Use a material which not absorb water. Stainless steel are the best possible none-hygroscopic material.
- * Reduce the sampling line to a minimum.
- * Heat and insulate the sampling line.
- * Install proper sampling probe.
- * Avoid sampling from a turbulent area.
- * Avoid a Joule - Thomson cooling effect upstream the hygrometer sensor.

FIELD EXPERIENCE MEASURING WATER DEWPOINT IN NATURAL GAS.

The water dewpoint monitoring system on Frigg which is a gas and condensate field, is based on both portable manual device and on-line automatic analysers. The philosophy is based on that the on-line automatic analyser shall monitor the water dewpoint continuously and the portable instrument which is a mirror type, is used as a "calibrating instrument" for the automatic analyser. The portable instrument is also used as a back up and spot check instrument. Figur 2 shows the location of the automatic dewpoint analyser and the location where the dewpoint most frequently is measured with the portable instrument.

Manual Dewpoint Techniques

The direct observation of dewpoint via a chilled mirrored surface using visual observation of the dew formation is a common and widely known method to measure the water dewpoint in natural gas. This method is also used for determining the hydrocarbon dewpoint. The hydrocarbon dewpoint is characterized by an rainbow colored film which radiates from the center of the mirror. The temperature and pressure where the iridescence first appear is the hydrocarbon dewpoint. Normally, further cooling of the mirror the water dewpoint will appear as an opaque cloudy spot near the center of the mirror. The temperature and pressure at which the opaque film first appears should be taken as the water dewpoint.

The hydrocarbone dewpoint can occur either at a different temperature (higher or lower) or at the same temperature as the water dewpoint and it has been reported that when hydrocarbones condense above the water dewpoint, it will interfere with the water dewpoint⁽³⁾. Further on, if the gas contains a number of components aside from the hydrocarbones, a great deal of difficulty may arise in the interpretation of the water dew point. The other components may condense slightly before or along with the water vapour and cause a masking of the mirror.

On Frigg, both glycol and condensed hydrocarbons are present and represent a potential problem. However, it has been possible to measure the water dewpoint with a satisfactory accuracy with the mirror type instrument. Sometimes the measurement has to be repeated and can take quite a long time to be performed. It can be very difficult to use under these conditions and requires an experienced, knowledgeable technician. If the hydrocarbon liquid makes it difficult or nearly impossible to measure the water dewpoint a small oil scrubber can be installed between the pipeline and the dewpoint tester.

Several references have discussed the above mentioned problems with condensate and glycol interfering the water dewpoint measurement (3,4,5). Some are of the opinion that downstream glycol dehydrators and with hydrocarbon condensate present, measurement of the true water dewpoint will not be possible. In this discussion it is important to know under which conditions glycol is present and the quantity of glycol and hydrocarbon condensate present.

Triethylenglycol (TEG) does not normally interfere (3,4) when TEG exists as vapour due to the low vapor pressure in natural gas. However, at times glycol are present as an aerosol one would expect it to be an interference. This will normally happen if the amount of glycol carried over from the dehydration plant is high. Foaming in the glycol dehydration tower will normally give a high amount of glycol mist in the gas. This effect has been experienced on Frigg and during this period it was nearly impossible to get stable and repeatable water dewpoint readings.

Two different portable mirror type dewpoint analysers are tested on Frigg. The first one was a Bureau of Mines Type Dew Point Tester developed by W.M. Deaton and E.M. Frost and manufactured by Chandler Engineering Company (Fig.3).

Used by experienced technicians this instrument gave satisfactory results. The accuracy claimed by the manufacturer to be 0.1°C under normal conditions but used under the conditions on Frigg the accuracy is not better than 2°C. The Bureau of Mines Type Dew Point Tester is quite easy to operate, however it does not satisfy the electrical safety requirements for installation in the North Sea.

Due to the problems with the Ex-certificate, a second portable dewpoint analyser were tested on Frigg, Optomat Ex from Hobre Instrumet b.v. This instrument is also using cooled mirror as measuring principle but it is easier to operate than the Bureau of Mines Type Dew Point Tester. The gas is cooled by a Beltier electric-element instead of cooling gas (CO₂, Propan).

This gives a much better control of the cooling process which is very critical when a mirror type instrument is used. Very often the mirror is cooled too fast and the water dewpoint will not get sufficient time to be built at the correct temperature and a lower reading will be the result. However, the mirror is very easily scratched and care must be taken when cleaning the mirror. Cleaning by means of acetone and instrument air is recommended.

Karl Fisher titration.

The Karl Fisher titration method has also been tested on Frigg. The experiences are that this method gives satisfactory results compared to the other methods. The Karl Fisher Titration which is tested on Frigg is based on the volumetric titration. This method is very time consuming and very flow dependent. If the Karl Fisher method is chosen, the coulometric titration principle should be used because this method is much faster than the volumetric method. As already mentioned, a portable version of this type is available but this does not have an Ex-certificate. The flow measurement is very critical for both methods and normally it is the largest source of error.

Automatic water dewpoint analyses.

The most difficult part of the water dewpoint monitoring has been to find an automatic water dewpoint analyser which can work under the Frigg process conditions. All of the automatic water dewpoint analysers available are more or less sensitive to glycol, deposits or hydrocarbon condensate poisoning, which are all present in the Frigg process.

Endress-Hauser WMY 370 automatic water dewpoint analyser was the first automatic analyser tested on Frigg. The Endress-Hauser utilizes the aluminium oxide sensor and measure the dewpoint under operating pressure. Fig.4 is a schematic recording of the installation. As can

been seen, the sample take off point is located just after the glycol dehydrator in a turbulent zone after a bend. A coalescer was installed to remove the liquids. The sampling line and the analyser cabinet was heated and insulated to avoid condensation of hydrocarbons and temperature variations. Although daily maintenance which included cleaning of sensor and the coalescer, the results never coincided with the manual readings over a longer period time. This system was also provided with a sample probe, but the location of it in a turbulent area after a bend, is not in accordance with good practice.

Next, a Shaw-SHA automatic water dewpoint analyser was tested. The Shaw-SHA analyser also utilizes the aluminium oxide sensor, but it is operated under atmosphere pressure. This means that the results has to be converted to operating pressure if the water dewpoint is wanted and that will increase the total uncertainty of the results due to the uncertainty of the converting methods which is available (6). The installation is shown schematically in Fig.5. The analyser did not give reliable results during the test. Similar to the Endress-Hauser, poisoning of the sensor by glycol and deposits gave false readings. The two Balston filters installed upstream the sensor did not protect the sensor efficiently but acted instead as a increased storage for glycol, giving the known effects as increased response time and false readings.

In addition to the problems with the glycol and deposits, this installation had due to the pressure reduction of about 150 Bar upstream the sensor a severe condensation problem. The Balston filter was filled with hydrocarbon condensate after a couple of hours.

The last automatic dewpoint analyser, Hygromat Modell 1100 from Hobre Instruments b.b., was installed a couple of months ago and is still being tested. The measuring principle is described in the chapter for Current Methods as the method utilizing the conductivity change in glycerol. The Hygromat Modell 1100 is operating at line pressure and there is no need of converting the water dewpoint. The cell temperature is maintained at 30° C by thermo-electric modules. The sensors are

identical and there is no need for recalibration when one cell is replaced by another. The sensor has normally to be replaced from two to four times a year. The reason for this is that the water which is absorbed into the glycerol normally will have a certain salt content and over a time periode the salt may be accumulated in the glycerol and cause a drift of the calibration curve.

A schematic recording of the installation is shown in Fig.6. The sample take off point is provided with a sample probe (Fig.1), located at the top of the pipeline. The sample line is made of non-hygroscopic stainless steel, heated by means of a self regulating heating tape and insulated. The water dewpoint analyser is located as close as possible and above the sampling probe without any U on the sampling line avoiding any accumulation of liquid. In order to reduce the effect of the Joule-Thomson cooling and reduce the hydrocarbon condensate build up in the flowmeter, the flow regulating valve is heated.

The analyser is located in a insulated stainless steel cabinet with an electric heater maintaining the temperature at 30°C.

The test during the first two months shows that the Hygromat Modell 1100 water dewpoint analyser is sensitive to glycol. However, foaming in the glycol towers with an increasing amount of glycol mist carried over in the gas has been a problem during these months. In spite of that, it has been possible to operate the analyser using a low flow through the sampling loope without any maintenance for a period up to three days. In addition the sensor can easily be cleaned by dry air. However, the results are not satisfactory, but without foaming this will most probably be better because the amount of glycol mist in the gas should decrease.

If it is not possible to increase the operating periode between the drying with instrument air, a liquid separator upstream the sensor will be tested. The two following methods described can be utilized without increasing the glycol accumulation too much. The first is a simple stainless steel Balston filter house (0,5cm³) with a continuous drain of liquid at the bottom. The second method available is a temperature filter system. The gas is cooled by thermo-electric modules to a preset temperature and the liquid is continuously drained off.

Conclusion.

- * Optomat Ex which is a mirror type manual and portable water dewpoint analyser has been tested and found reliable for natural gas application. Glycol mist carried over from dehydration plant and hydrocarbon condensate will cause problems if it is present in high concentration. Any manual mirror water dewpoint analyser must be operated by experienced technicians.

- * The volumetric Karl Fisher method has also been tested and found useable for natural gas application. Glycol and liquid hydrocarbon do not interfere with the results. The volumetric Karl Fisher method is time consuming and if the Karl Fisher method shall be used the coulometric method is recommended. A portable version is available but this is not Ex-proof.

- * Two automatic on-line water dewpoint analysers, Endress-Hauser WMY 370 and Hygromat Modell 1100, with an aluminium oxide sensor has been tested and found not useable in natural gas application downstream glycol dehydration towers. Filters and coalescers will not remove all glycol, hydrocarbon liquid and deposits present in the natural gas.

- * A Hygromat Modell 1100 automatic on-line water dewpoint analyser has also been tested in natural gas under the same conditions. The analyser is found to be sensitive to glycol, but can be operated for a period of three days without maintenance even under a relatively high amount of glycol mist in the gas. The Hygromat Modell 1100 analyser can be cleaned by instrument air. The test is not completed, but the results so far are promising.

LITTERATURE PREFERENCES

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FIG. 1 SAMPLING PROBE

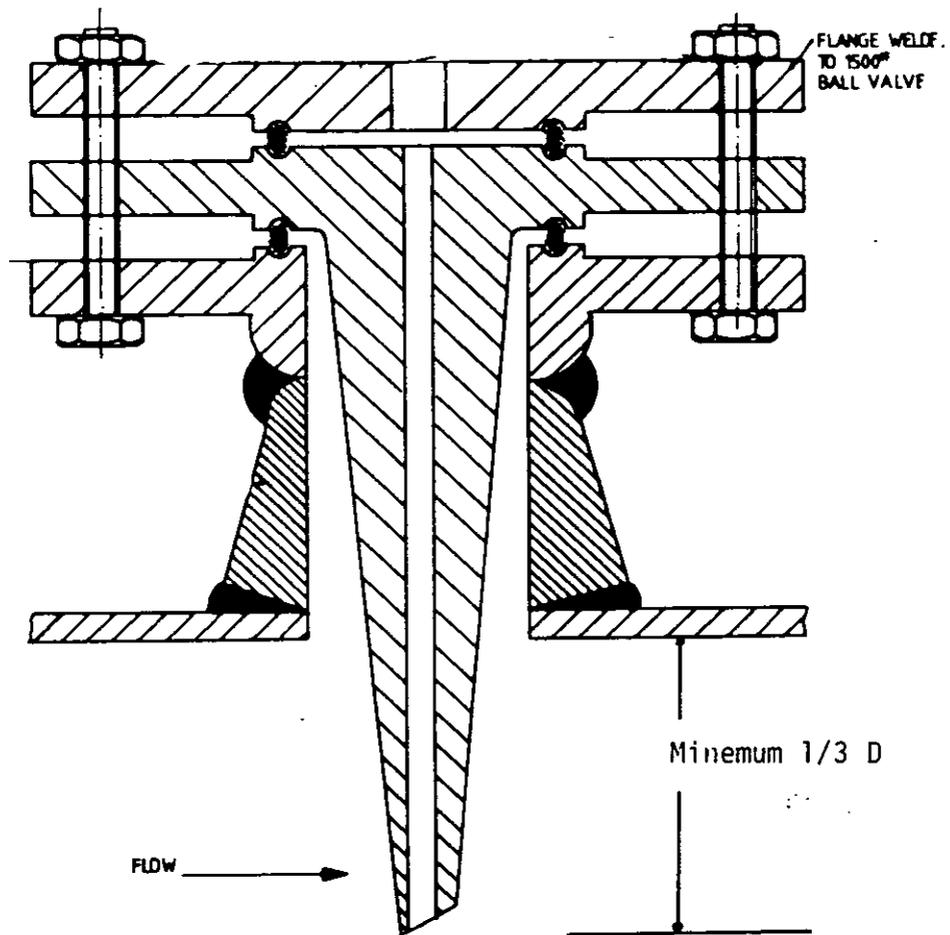
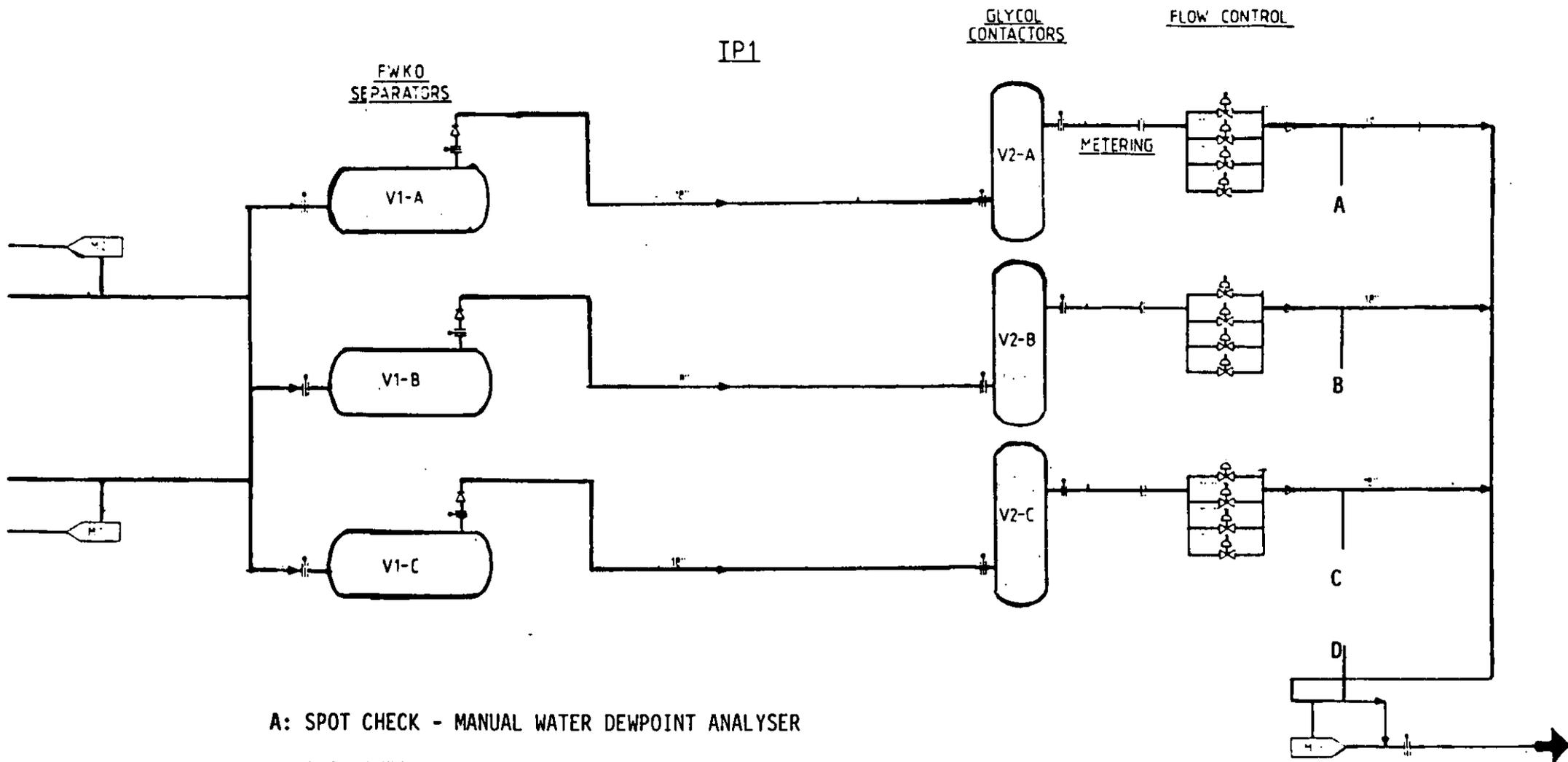
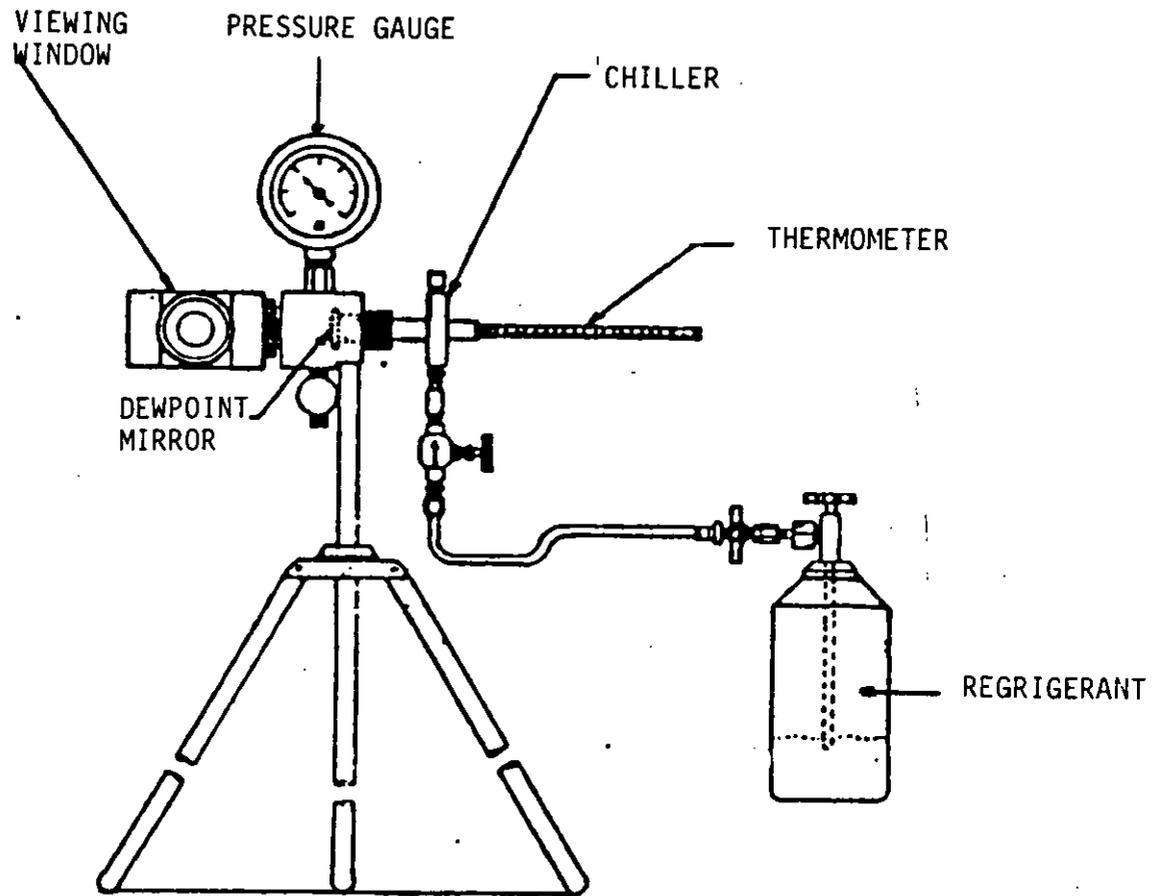


FIG. 2 FRIGG GAS PROCESS FLOW

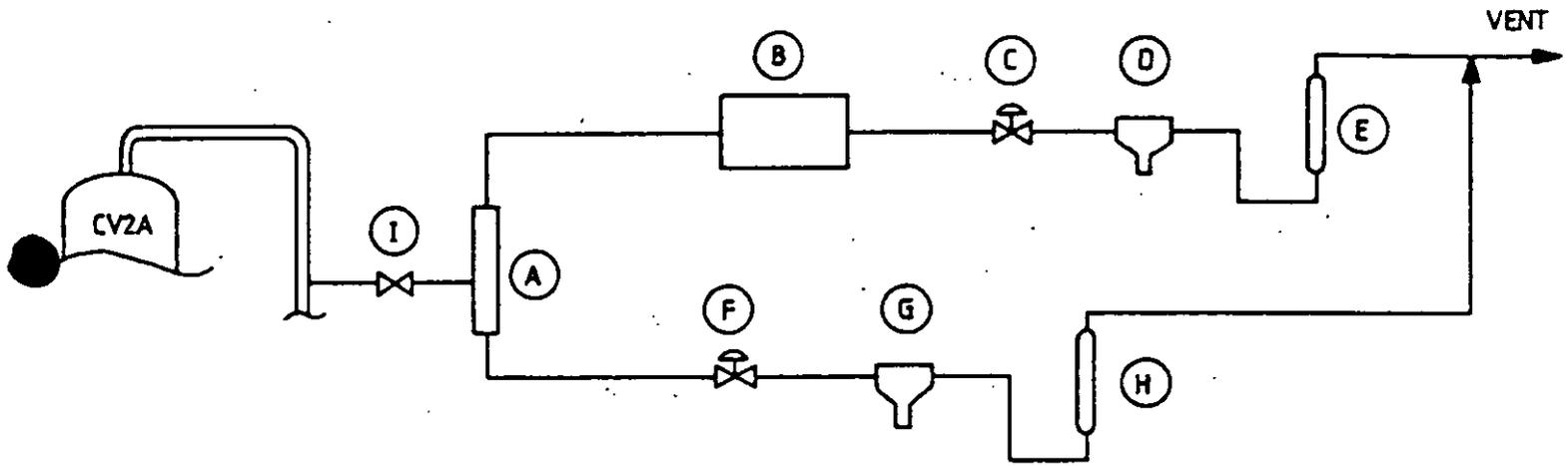


- A: SPOT CHECK - MANUAL WATER DEWPOINT ANALYSER
- B: SPOT CHECK - MANUAL WATER DEWPOINT ANALYSER
- C: SPOT CHECK - MANUAL WATER DEWPOINT ANALYSER
- D: AUTOMATIC DEWPOINT ANALYSER

FIG. 3 BUREAU OF MINERS DEWPOINT TESTER CHANDLER
ENGINEERING COMPANY

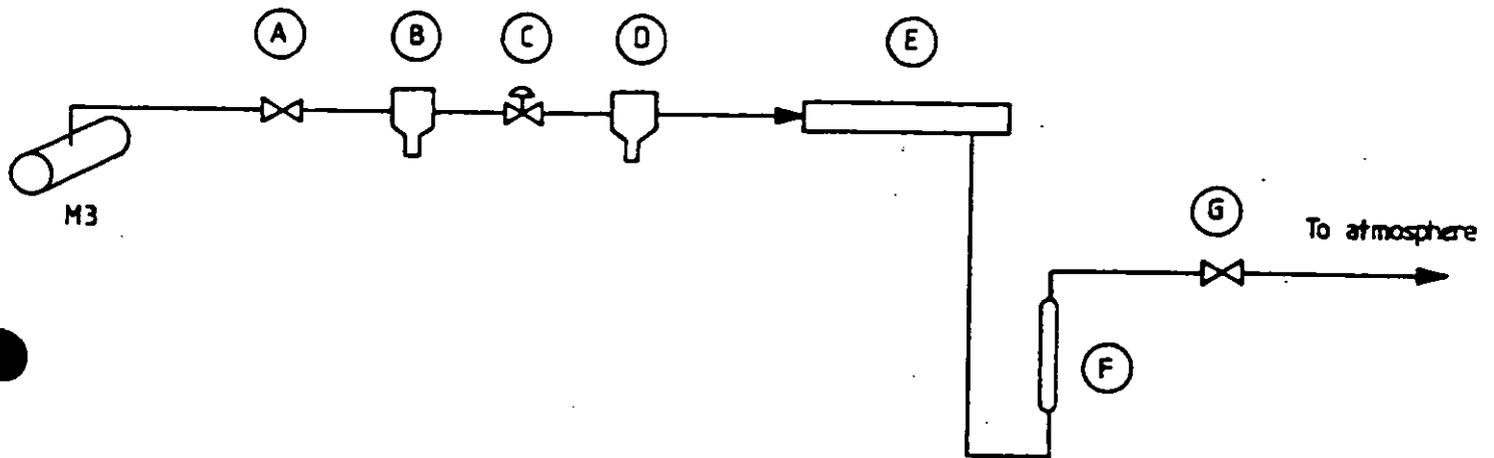


**FIG. 4 ENDRESS-HAUSER WATER DEWPOINT ANALYSER
INSTALLATION**



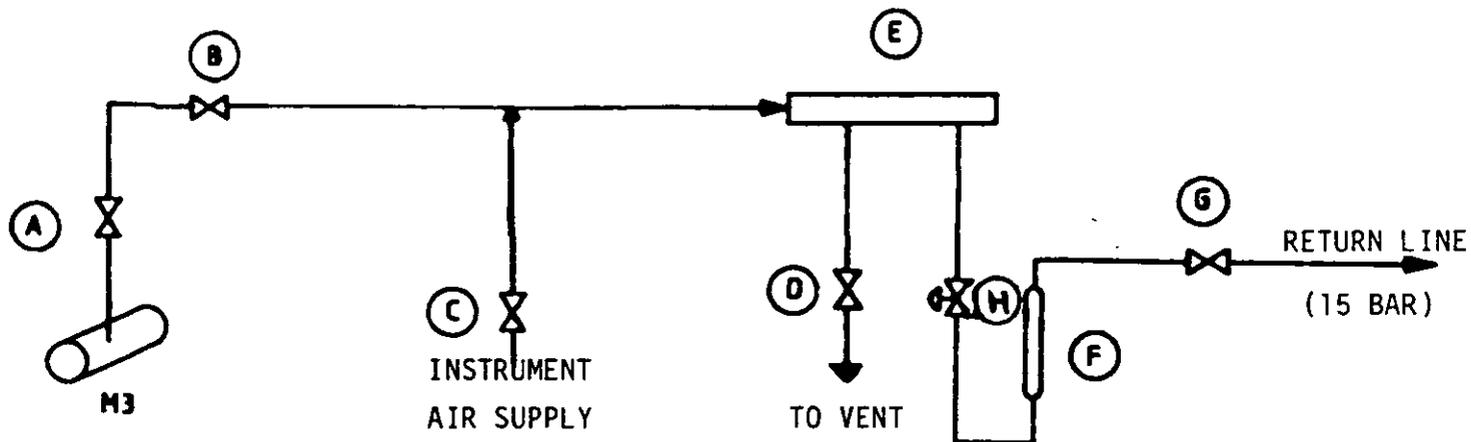
- (A) Coalescer
- (B) Sensor
- (C) Flow regulation valve
- (D) Balston filter
- (E) Flowmeter
- (F) Flow regulation valve
- (G) Balston filter
- (H) Flow meter
- (I) Valve

FIG. 5 SHAW WATER DEWPOINT ANALYSER INSTALLATION



- (A) Ball valve
- (B) Balston filter
- (C) Flow regulation valve
- (D) Balston filter
- (E) Sensor
- (F) Flow meter
- (G) Valve

**FIG. 6. HYGRAMAT MODELL 1100 DEWPOINT ANALYSER
INSTALLATION**



- (A) BALL VALVE
- (B) BALL VALVE , INLET
- (C) BALL VALVE
- (D) BALL VALVE
- (E) SENSOR
- (F) FLOWMETER
- (G) BALL VALVE, OUTLET
- (H) FLOW REGULATION VALVE