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# FLOW COMPUTERS AND TRANSMITTERS IN ORIFICE METERING SYSTEMS FOR GAS

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## INTRODUCTION

In this lecture I have chosen to illustrate the use of flow computers and transmitters in orifice metering systems for gas by taking the new metering system on the Frigg field as an example. The basic layout of the system is shown Fig.1 and the architecture of the system is selected with both consideration to the general layout of platforms on the field and the wish to have the metering system available without degradation in metering accuracy during a number of fault conditions.

The general layout of the Frigg field is shown in Fig.2. The total number of platforms on the field is five. The gas from the wells platforms CDP1 and DP2 is transported to treatment platforms TP1 and TCP2 respectively via 26 inch pipelines. On production platforms TP1 and TCP2 the gas is treated to achieve the required water dewpoint specification where also the metering takes place before the gas enters the 32 inch pipeline for transportation to the St.Fergus terminal in Scotland.

This information is hopefully adequate as background information and I will now continue to talk about the details of the system.
Referring back to fig. 1 we can see that the transmitters which provide inputs to the flow computers are:

- Density
- Differential Pressure
- Static line Pressure
- Temperature.

In addition to a functional description/special installation requirements of the flow computers and the above sensors, I will also talk about calibration and maintenance ascpects. Some of the comments given in this lecture represent ideas generated from my own personal experience and I do not of course consider these to be universal acceptable but rather input to a debate where the aim is to achieve metering system with maximum accuracy combined with minimum maintenance efforts.

FLOW COMPUTERS

The new flow computers on the Frigg field due to be delivered in August this year are made by the english firm Spectra-tek UK Ltd. Elf selecte these particular models due to the flexibility in adapting them to the our special requirements.

a) 869 R Stream Measurement Microcomputer
b) 869 V Central Control Microcomputer
c) 869 V Database computer

The computers are based on a modular electronics system enabling them to be configured for their specified tasks by selecting the appropriate plant interface cards, carrying out the corresponding back-plane wiring and finally writing the application software. The heart in these flow computers is the central Processor unit incorporating the Motorala MC 6809 MPU chip.

From my point of view the integrity or the security of the system is very important when selecting one of the many flow computers available on the market.

In our case the control programmes are ROM based requiring no initialisation or commissioning procedure. This form of memory is highly secure and not prone to the obscure corruption which can, and often does, occur in core based minicomputers. In my view the exclusive use of ROM for the control programmes is essential to the security and reliability of the system.

One should be able to modify the calculation parameters held in RAM, but on-line changes to the control programme are highly undesirable.If necessary, changes in calculations can be implemented off-line and fully tested before being incorporated into the control program.

We shall now take a closer look at the Software Security features which are incorporataed in the machine.

a) All running totals and other vital data are held simultaneously in three separate registers. During each programme, loop a check routine is performed to ensure that the data is identical in all three registers. If one register of the three should ever disagree with the other two, this is a triple register "partial failure", annunciated as an alarm. Upon alarm acceptance the computer attempts to correct the erroneous version. In the event of total triple register disruption, ie none of the three registers agree, then a triple register total failure is annunciated, which cannot be corrected automatically.

This feature means that in the absence of tri-register alarms, confidence in data security can be justifiably high, and should data corruption ever occur, then this is annunciated immediately.

b) During each programme loop a check routine will be executed to verify the logical and arithmetic operation of the CPU itself.

c) A creeping RAM monitor routine is used to verify the read/write operation of every location in the RAM memory. The routine is run as a background activity in which taking each location in sequence, the microprocessor stores the memory location data in a register, then writes and reads test patterns of data into the location before replacing the data and moving on to the next location. Any location failing the test raises an alarm, and the instrument indicates the identity of the faulty card.

d) A ROM integrity check routine is incorporated based on the use of checksums in every ROM chip.

e) An independent hardware timer (Watchdog) is provided to detect collapse of the system in terms of orderly programme execution.

f) A power supply monitor routine is used to detect imminent supply failure enabling the machine to secure data and shut down in an orderly manner.

g) All communication between microcomputers relies on rigorous interactive protocol to ensure high security.

Another very important feature of any metering system is availability. It is not acceptable to have the metering capacity reduced for long periods of time in order to perform maintenance and repairs.

Referring back to figure 1 it is seen that the metering concept is based upon the idea of decentralisation. The task of computing the flow rate, monitoring process conditions etc. is done as close as possible to the process elements themselves. Should an error situation occur, the influence on the metering capacity of the system is minimal.

As seen from the figure each meter run is equipped with a dedicated micro computer with complete autonomy with respect to its tasks.

Typical inputs to the machine are differential pressure, static pressure temperature and density. From these inputs volume and massflowrate are calculated on a continuous basis.

Two bidirectional serial data ports are provided on each of the stream micro computers to allow independent communication with the central control room machine CCM (located in the interface room on TP1), and with the CCM on TCP2 via data highway no.2. With this set up the information from the stream machine has alternative paths should either of the CCM fail.

During normal operation the micro computer located in the control room on QP (the data base computer DBM) controls the operation of the entire system.

From the keyboard on the DBM the control room operator addresses and initialises the stream machine directly. The operator can also ask for a display of data, working constants etc. presently used by the stream machines.

During normal operation the DBM is the master and communicates with CCM1 or CCM2 which again is responsible for down-loading the information to the stream machines.

Other tasks of the DBM are:

- To form a constantly updated database.
- To check the integrity of the CCM.
- To format and print the daily production log.

Should during an abnormal situation, the DBM cease to operate, its function of being a master will be taken over by the CCM.
Another important task of the CCM is to communicate with a dual casette recorder containing all the data pertinent to the stream micro computer. All the data stored on tape can be displayed on the CCM's data screen. Should any of the data need to be changed this can be done using the keypad on the CCM. Dual casette recording is provided so the original data is kept on the tape while the technician is editing the other.

The alarm and reporting function of the DBM is in this mode controlled by the CCM.
Since the CCM has 100% back up with respect to its tasks, normal production reporting will be provided in most situations because the changes that both CCM machines fail at the same time are considered to be minimal.

Another feature of the CCM is that data entered by the operator during for example a change of orifice are automatically compared to a pre-programmed list of permissible values stored in the CCM. Further transmission of data to the relevant SMM will only take place if the entered values agree with allowable orifice diameters and bore numbers.

Finally, the CCM checks the integrity of the stream machines by monitoring the SMM self check alarm flag in addition to the coherence of the transmitted data itself.

The back-up to the stream machine is considered to be made up by the large amount of meter tubes. The metering capacity on the Frigg field is approx 100 MMSCM while the max production is in the order of 65 MMSCM.

Therefore should a stream machine fail, immediate alarm is raised and the operator shut down that particular stream from the control room.

Finally, the integrity requirement to a fiscal metering system is very stringent. Therefore the parameters available for operator entry are limited to:

- Operating mode (Meter, Change orifice, Calibration or Initialisation).
- Orifice number and orifice bore diameter.

Other data may also be over written, but it is offered an extra level of security i.e security code must first be entered successfully before data can be entered in conjunction with the data entry key switch.

In this manner, system integrity is satisfied.

CALIBRATION / MAINTENANCE

Another great advantage with modern digital micro computers is that self checking facilities as described earlier are provided. Therefore, the traditional maintenance aspect as experienced with "old" analoge computers has dissappeared.
However, an element which should not be forgotten is the analoge to digital converter. Since a slight error in this unit will cause a systematic error in all parameters, particular attention should be paid to self checking facilities and regular calibration monitoring. The A/D converter to be used on the Frigg field has both automatic zero and span correction. During the auto-zero phase the total on-card offsets are measured, stored and subtraced. This effectively achieves a zero drift of 2 micro V/$^{o}$C allowing a 50$^{o}$C ambient shift before one count has been passed.

Span correction is achieved using a very high precision reference unit mounted in the micro computer and forming one of the scanned inputs of the system. The micro computer will scan this known voltage and store the converted digital number in its memory. The precise value of the chosen reference, obtained by commissioning measurement using a certified transfer standard voltmeter, can be stored in the computer memory using the key pad facilities on the computer front. Subsequent readings of all other channels will be ratioed by software to account for the error between the keypad entered value and the value measured by the ADC.

## DENSITY MEASUREMENT

### Principle of operation

The density transmitter which will be used on the Frigg field is manufactured by Solarton. The type 7811 has been chosen and is specially designed for high static pressure operation.

The operation principle of the transducer is shown in Fig.3. The transducer sensing element consists of a thin cylinder which is actuated so that it vibrates in a hoop mode at its natural frequency.

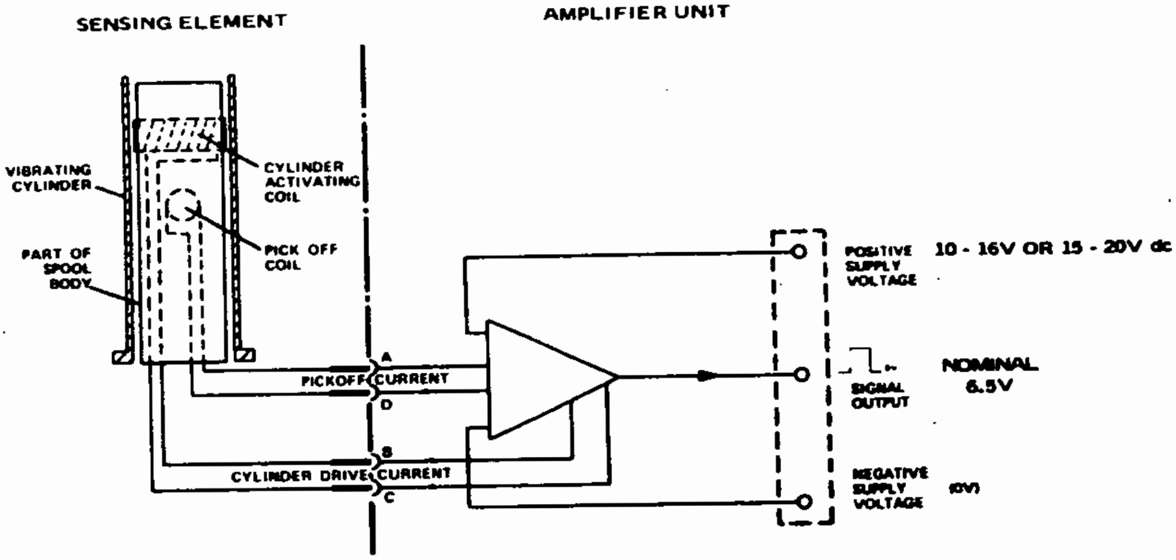



FIG. 3 Schematic Block Diagram of Transducer Cicruit.

The gas is passed over the inner and outer surfaces of the cylinder and is thus in contact with the vibrating walls.
The mass of gas which vibrates with the cylinder depends upon the gas density and, since increasing the vibrating mass decreases the natural frequency of vibration, the gas density for any particular frequency of vibration can be determined from the formulae:

$K_0, K_1 + K_2$ CONST.

$$\rho = K_0 + K_1T + K_2T^2$$

PERIODIC FREQUENCY

INSTALLATION OF DENSITYMETER

Ideally the density transducer should be located within the flowing gas adjacent to the reference volume metering plane. In ISO 5167 the metering plan is defined as the plane of the upstream pressure tapping point (ref section 3.4).

It is of course not permissible to install the density transducer in the pipe directly upstream of an orifice plate, because this would disturb the gas flow pattern at the orifice and cause errors in flow measurement.

So the task from an engineer's point of view will be to install the density meter elsewhere and minimise the difference in operating conditions between the density transducer and those at the volume metering plane.

Prior to making the final selection, efforts should be made to minimise the errors associated with the following points:

a) Effects on the density transducer itself;
   for example, temperature and pressure coefficients, flowrate effects attitude, accuracy of calibration, effects of velocity of sound, etc.

b) Temperature and pressure differences between the gas at the metering plane and the gas in the density transducer.

c) Adequate filtration / conditioning to prevent dirt or condensation from causing maloperation of the transducer.

d) Unregistered gas which passes through the density meter but not the flow meter.

When using a Solarton transducer, the final installation must be designed in order to obtain a representative gas sample stream. This consideration excludes using the upstream flange pressure point as origin for the slip stream. A complete analysis of the flow pattern at this point will not be provided here, but the sudden increase in gas velocity in front of the orifice plate will affect the components in the gas differently thus making the flange taps point unsuitable for obtaining a representative sample

With this in mind we are left to consider the two alternatives shown in Fig.4A and 4B respectively.

In both alternatives the density transducers are located in a thermowell thus making sure that the gas in the density meter has the same temperature as the gas in the main line. However, in figure 4B the sample point is located upstream satisfying the free straight lenght requirements of ISO 5167, but a pressure drop will occur along the sample pipe to the density transducer. Therefore the pressure in the density will be different to the pressure of the metering plane.

At Frigg it will be necessary to install an additional filter in the sample stream thus increasing this pressure drop. But the most severe limitation with this method is that it is difficult to account for the pressure drop.

In the majority of the offshore installations, the static line pressure is 100 - 200 Bar. Therefore equipment is not available to measure the very much smaller pressure drop in the sample line. Hence, it is not known how to account for this in the massflow calculations.

An additional disadvantage with this method is that the slip stream is not registered by the flowmeter and thus give rise to a systematic error which however small should be accounted for. An estimate of this error may be obtained by refering to the section on drain holes in British standard BS 1042 or similar documents.

The alternative arrangement shown in Fig. 4A provide the same good temperature equalisation as fig. 4B. The sample point in this case is taken downstream of the orifice carrier and the gas slip stream returned to the downstream flange tap. In this arrangement, the length of the sample return line is very short. Therefore the additional pressure drop may be neglected and the pressure in the density transducer is equal to the pressure at the downstream flang tap P2. Additional filtering installed in the sample line will in this case not interfere with the density measurement.

However, the density is determined at the downstream flange tap and the metering plane is as stated previously the upstream flange tap. Using the above arrangement require the basic mass flow equation to be modified, this means that the expansion coefficient at the downstream flange tap must be calculated.

For a given flow meter and flow rate the position where is measured and the corresponding must give the same answer.

$$W = CZE\varepsilon_1 a\sqrt{h\rho 1} = CZE\,\varepsilon_2\ a\sqrt{h\rho_2}$$

$$\text{giving:}\ \varepsilon 1\sqrt{\rho 1} = \varepsilon 2\sqrt{\rho 2}$$

where: $\varepsilon_1$ = expansion coefficient at the upstream flange tap.

$\rho_1$ = Density at the upstream flange tap.

$\varepsilon_2$ = Expansion coefficient at the downstream flange tap.

$\rho_2$ = Density at the downstream flange tap.

If the small differences in density can be considered directly proportional to the small pressure difference.
(iso-thermal approximation)

Giving: $\rho_1 \propto P_1$ , $\rho_2 \propto P_2$

Where h = differential pressure across orifice

then one can write : $\varepsilon_2 = \varepsilon_1 \sqrt{P_1/P_2} = \varepsilon_1 \sqrt{\frac{P_1}{P_1 - h}}$

The above method is described in the new draft proposal for the British standard on orifice measurement Part II of BS 1042. In addition AGA 3 provide a formular for calculating $_2$ at the downstream pipe tap,

$$\varepsilon 2 = \sqrt{1 + X} - \frac{BX}{\gamma \sqrt{1 + X}}$$

and $B = 0,333 + 1.145\ (\beta^2 + 0.7\beta^{5} + 12\beta^{13})$

Note that in this case for X = h/p, h is the differential pressure form pipe taps. If h is measured with flange taps the following correlation can be used

$$\frac{h\ (\text{pipe taps})}{h\ (\text{flange taps})} = 1 - 1{,}08\beta^2$$

## CALIBRATION

The procedure to be used on the Frigg field when calibrating the Solarton transducer is still being considered, and I will therefore just offer some general comments on the matter. Normally the calibration of the Solarton transducer is carried out off-line and it is necessary to correct the basic calibration coefficients to take into account the difference in velocity of sound between Frigg gas and the calibration gas.

However, our experience so far is that once the Solartron has been calibrated it will maintain calibration for a very long period of time.

As a continuous monitoring of the density transducer one additional function of the stream micro computer is to calculate density from P & T measurement and compare the theoretical value to the measured density. An alarm will be given if the difference exceed a preprogrammable limit. It is our intention that this facility will enable us to maintain the instrument within the desired accuracy limits.

## DIFFERENTIAL AND STATIC PRESSURE MEASUREMENTS

The sensors which are used for these measurement on the Frigg field are the well known transmitters form Rosemount and Foxboro.

Rosemont 1151 HP is used for differential pressure measurements and Foxboro E11GH is used for the static pressure measurements.

Calibration

The static pressure transmitter is calibrated on line using a deadweightester from Chandler engineering Ltd.
The instrument is rugged and well suited for the accuracy required. ($< 0.3\%$).

However, the calibration of the dp cells is more elaborate as there is no equipment available with the required accuracy suitable for field use.

The sensor has therefore to be disconnected and brought to a place where it can be calibrated under controlled environmental conditions using a Degranges & Huot dead-weight tester.

It turned out that the only place suitable for this activity was the living quater platform QP. Even there under difficult weather conditions the vibrations in the structure is such that it is impossible to carry out the calibration.

## TEMPERATURE MEASUREMENT

Gas temperature is measured by a Platinum Resistance Thermometer manufactured to BS 1904 Grad 1 having a resistance of 100.0 Ohms at $0^oC$ and a fundamental interval of 38.5 Ohms.

The PRT will be connected by a four-wire, screened arrangement to the metering cubicle terminals and within the cubicle to the SMM.

Temperature measurement is self powered, no external power supplies shall be required. Two of the four PRT wires and the PRT element itself form a current loop carrrying some 2.8mA circulated by a current source which forms part of the ADC. The remaining two wires channel the p.d developed across the PRT (caused by the 2.8mA flow through the resistance) into the voltage sensing input of the ADC which has a very high input resistance resulting in a negligible voltage drop in the cabling. The ADC ratios the current magnitude to sensed voltage and yields a count which proportional the PRT resistance yet insensitive to cabling resistance therefore accurate.

The SMM software will convert the measured PRT resistance to a temperature reading using the Calender Van Deusen relationship.

Accuracy: + 0.1°C in resistance measurement terms, but
+ 0.2°C taking transducer interchangability errors into account.

Calibration

The calibration of the temperature measurement loop is performed by simulating resistance values from the field according to the British Standard BS 1904. Using a high precision certified resistance bridge. The simulated values can then be compared to the printout from the CCM or DBM micro machines.

Although the platinum elements themselves are more stable than thermo-elements, their temperature / resistance relationship do change with time. Exposure to high temperature will accelerate his change.

Very often this is overlooked and systematic errors in the order of 0,5°C - 1° can occur if recertification of Pt 100 elements are not performed as part of the regular maintenance plan.

The frequency of this recertification can vary from one installation to another depending on how high temperature the elements are exposed to.

But recertification at 12 months intervals could be used as a starting point.

An easy check which should be performed on the field on a regular basis is to insert the Pt 100 element into a thermo bottle containing mixture of ice / water, noting the temperature measured by the stream microcomputer.

Changes in the Platinum characteristics can in this manner be detected at any early stage.

Stavanger 14.5.1982

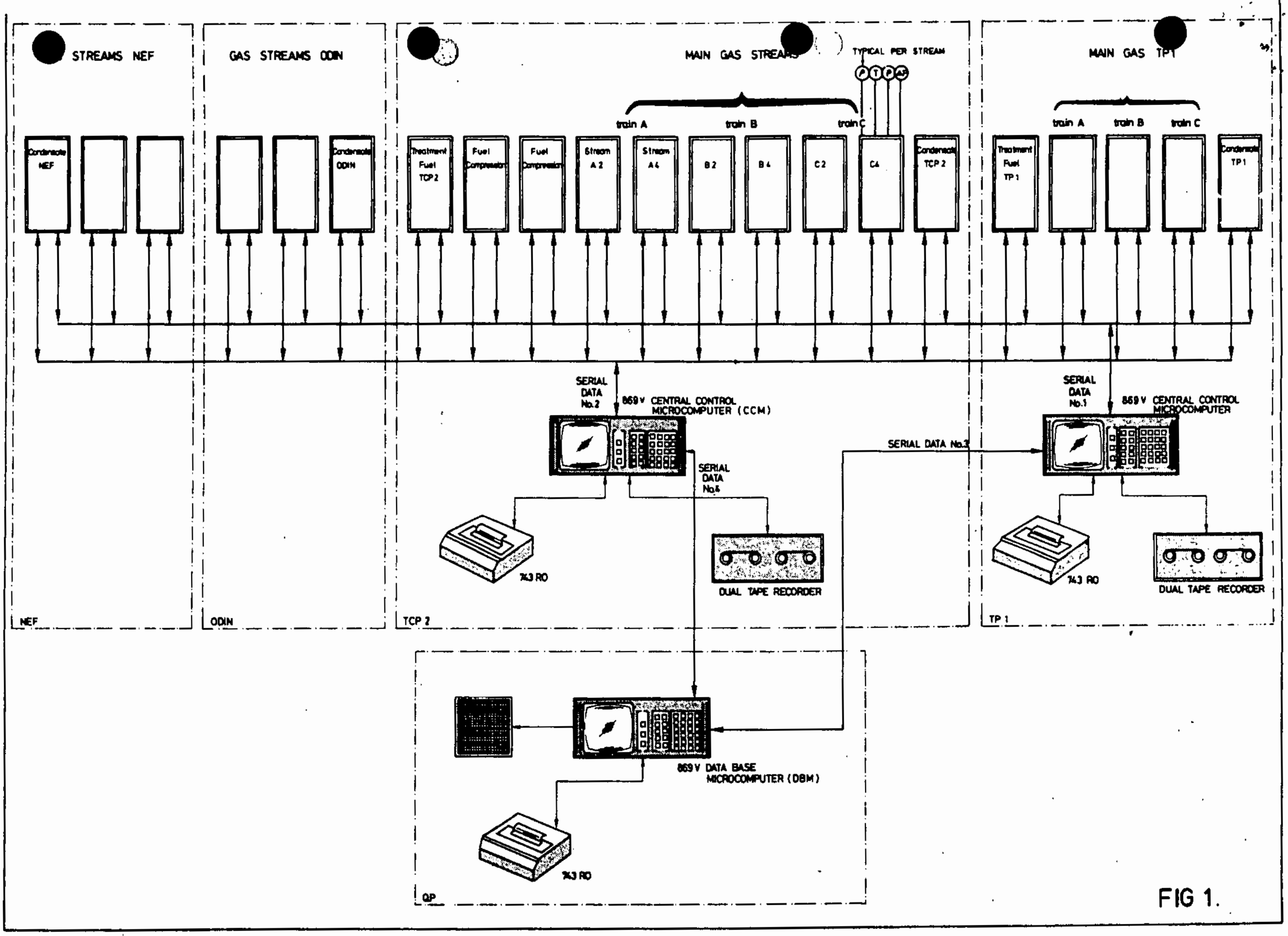
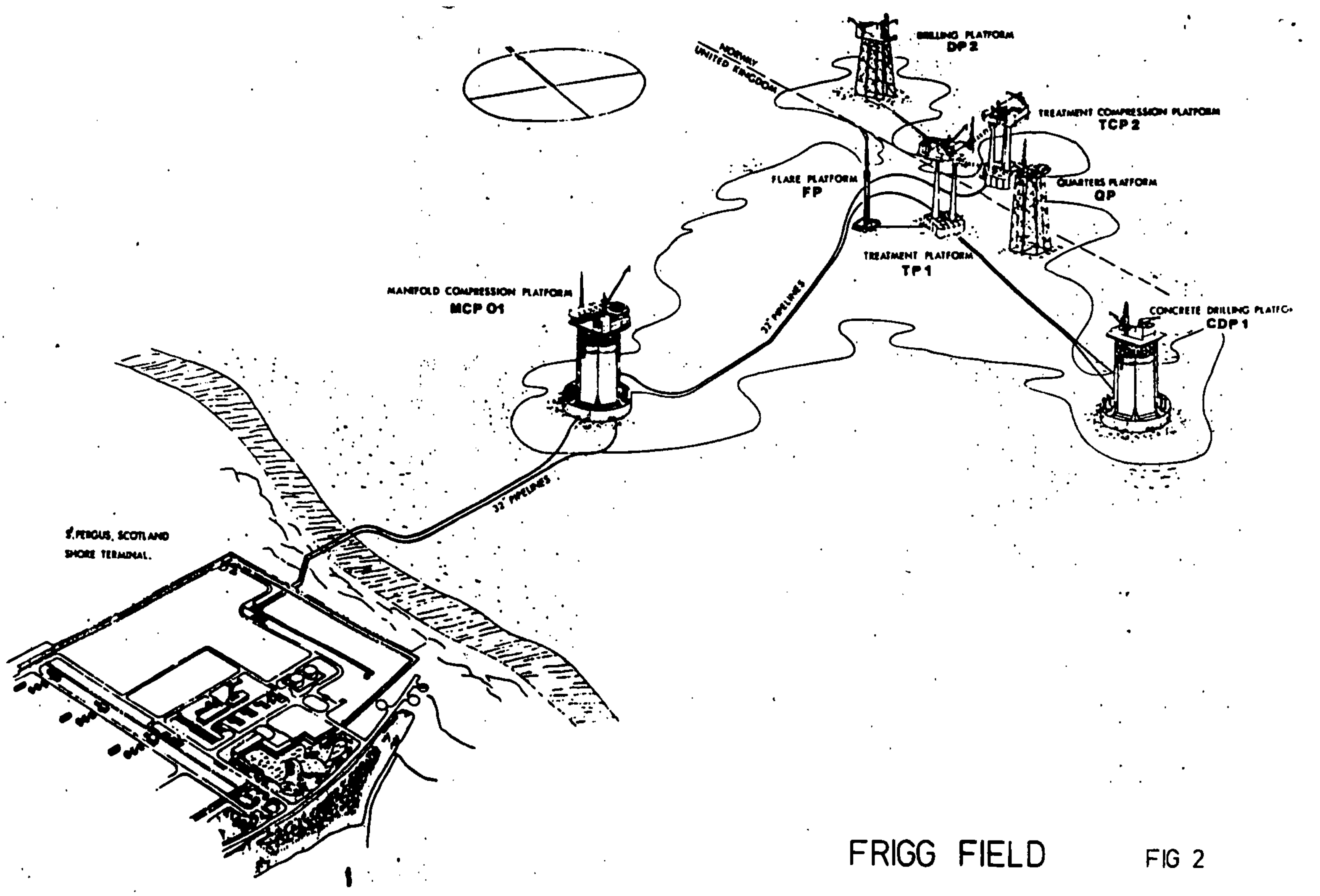
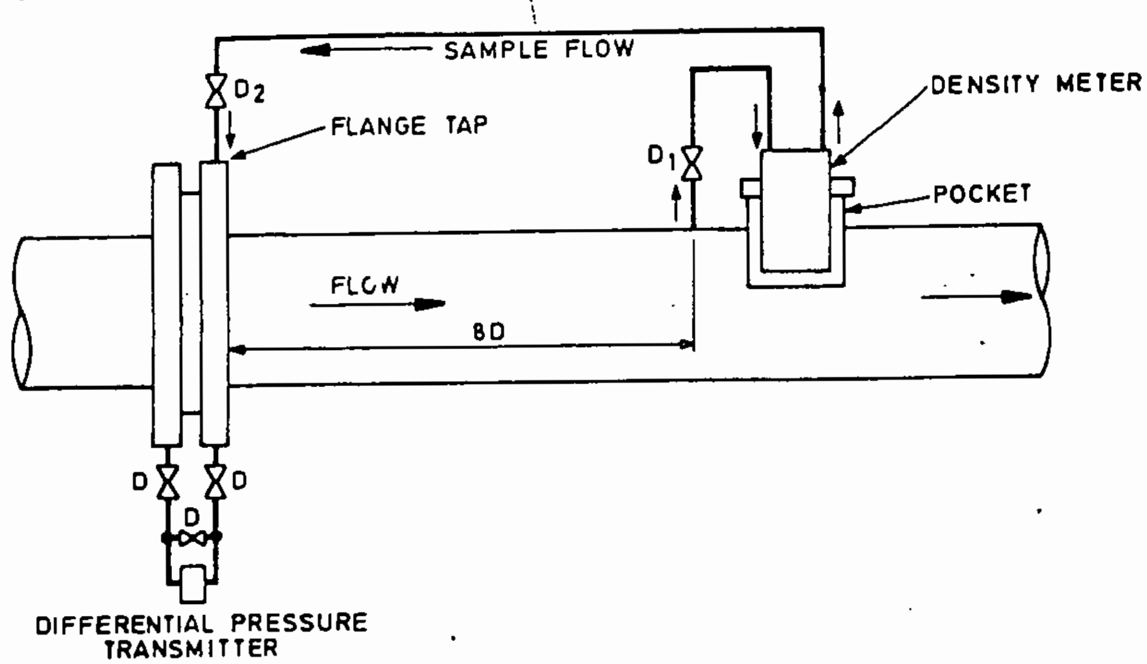

STREAMS NEF
GAS STREAMS ODIN
MAIN GAS STREA
TYPICAL PER STREAM
MAIN GAS TP
train A
train B
train C
Condensate NEF
Condensate ODIN
Treatment Fuel TCP 2
Fuel Compression
Fuel Compression
Stream A 2
Stream A 4
B 2
B 4
C 2
C4
Condensate TCP 2
Treatment Fuel TP 1
Condensate TP 1
SERIAL DATA No.2
869 V CENTRAL CONTROL MICROCOMPUTER (CCM)
SERIAL DATA No.4
SERIAL DATA No.3
SERIAL DATA No.1
869 V CENTRAL CONTROL MICROCOMPUTER
743 RO
DUAL TAPE RECORDER
NEF
ODIN
TCP 2
TP 1
869 V DATA BASE MICROCOMPUTER (DBM)
QP

FIG 1.



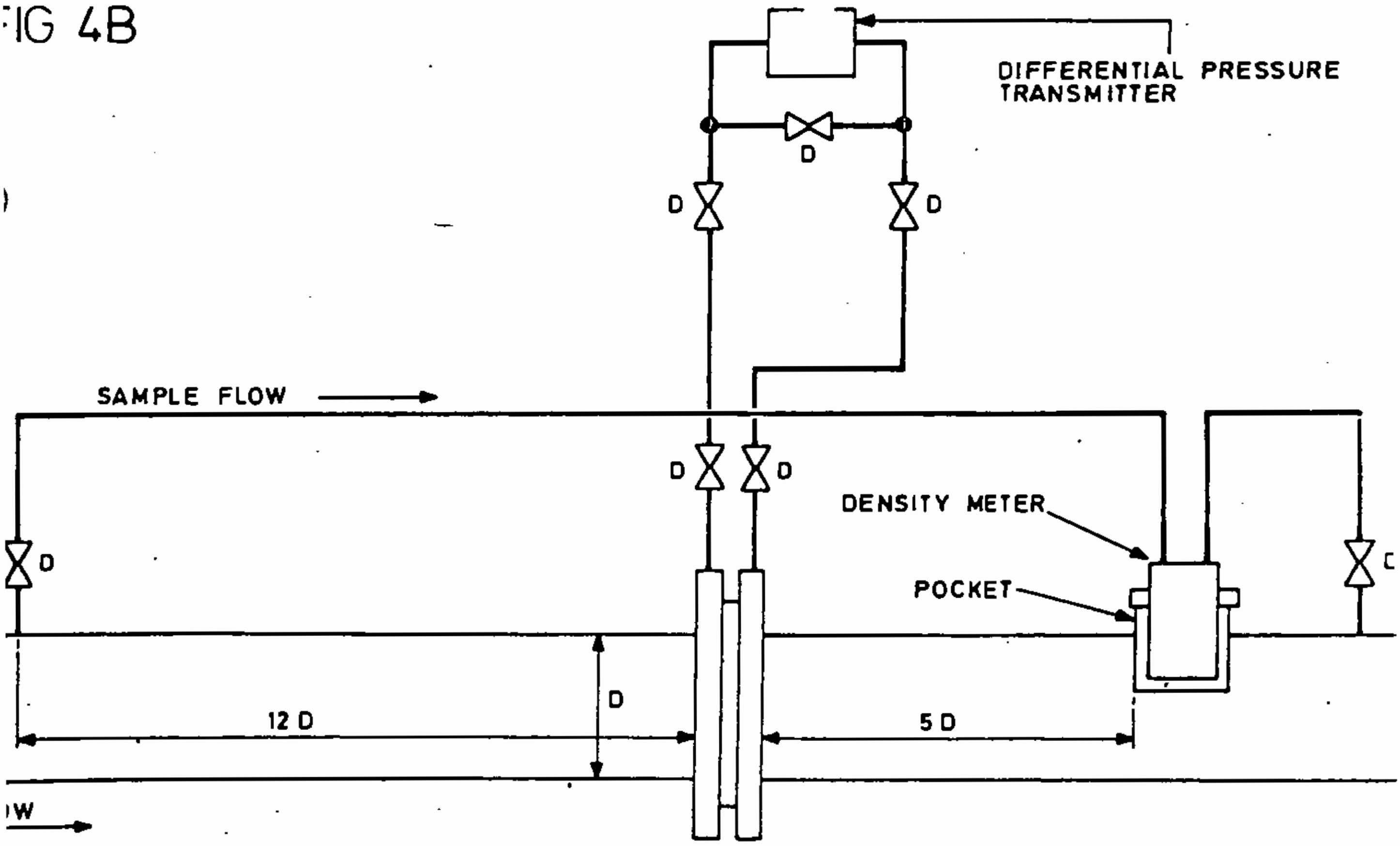

FRIGG FIELD FIG 2

FIG 4A




INSTALLATION OF GAS DENSITY METER ON AN ORIFICE PLATE SYSTEM USING THE PRESSURE RECOVERY METHOD

FIG 4B




BY-PASS INSTALLATION - POCKET METHOD

## 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.