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IN-SITU CALIBRATION OF FLARE GAS FLOW METERING SYSTEMS

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IN-SITU CALIBRATION OF FLARE GAS FLOW METERING SYSTEMS

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SUMMARY

The use of gaseous tracers permits efficient and reliable measurements of linear flow velocity of gas in flare systems under normal production conditions and covering the full range of flow rates.

The method is based upon the international standard ISO 4053/IV. A small amount of radioactive gas is injected into the flare gas stream, and the transit time for the tracer cloud between two radiation detectors outside the pipe is recorded.

Since 1983, FORCE Institute has carried out yearly measurements on all flare gas systems on Danish offshore platforms.

Flow velocities ranging from a few centimetres/second to more than 100 metres/second are covered using the same instruments and set-up.

The accuracy obtained depends on practical possibilities for injection, the available length of measuring distances, and the stationarity of the flow. Under typical conditions an accuracy better than ±1% is obtained.

The most commonly used gas tracer is the noble gas krypton as the Kr-85 isotope.

INTRODUCTION

Gas flaring in offshore installations represents a source of loss of energy making it important to operators and authorities to monitor the amounts of flared gas. In some countries the flare gas is subject to CO_2 tax. Flow metering systems are installed on some but not all flare systems.

In situ control and calibration of flare gas metering systems or in situ measurements of flare gas flow where no meters are installed can be performed by the gaseous tracer method without affecting the normal production and covering the large dynamic range of flow rates.

The concept of tracers implies the addition to a main flow stream of a small amount of a substance that flows with the main stream without distorting the flow. Measurements of variation with time of the tracer concentration reveals information about the main stream.

Radioactive tracers are isotopes of different elements in suitable chemical forms. Radioactive tracers can be measured in very small concentrations, and since the natural occurrence is none or very small, the signal to noise ratio for measuring radioactive tracers is very favourable.

METHODOLOGY

The gaseous tracer method yields the equivalent piston flow linear velocity of the gas flow in the pipe without any constraints regarding flow regime under the conditions prevailing for flare gas flow.

For calculation of the volumetric flow rate only the cross section area of the pipe is to be known. In order to give flow under standard conditions the temperature and pressure must be measured, and for conversion to mass flow the composition or density of the gas must be determined. These process parameters are often monitored by calibrated instrumentation.

The method is based on the international standard ISO 4053/IV, /1/. A small amount of the radioactive tracer is injected instantaneously into the flare gas flow through e.g. a valve, representing the only physical interference with the process. Radiation detectors are mounted outside the pipe and the variation of tracer concentration with time is recorded as the tracer moves with the gas stream and passes by the detectors.

The measuring principle is illustrated in figure 1.

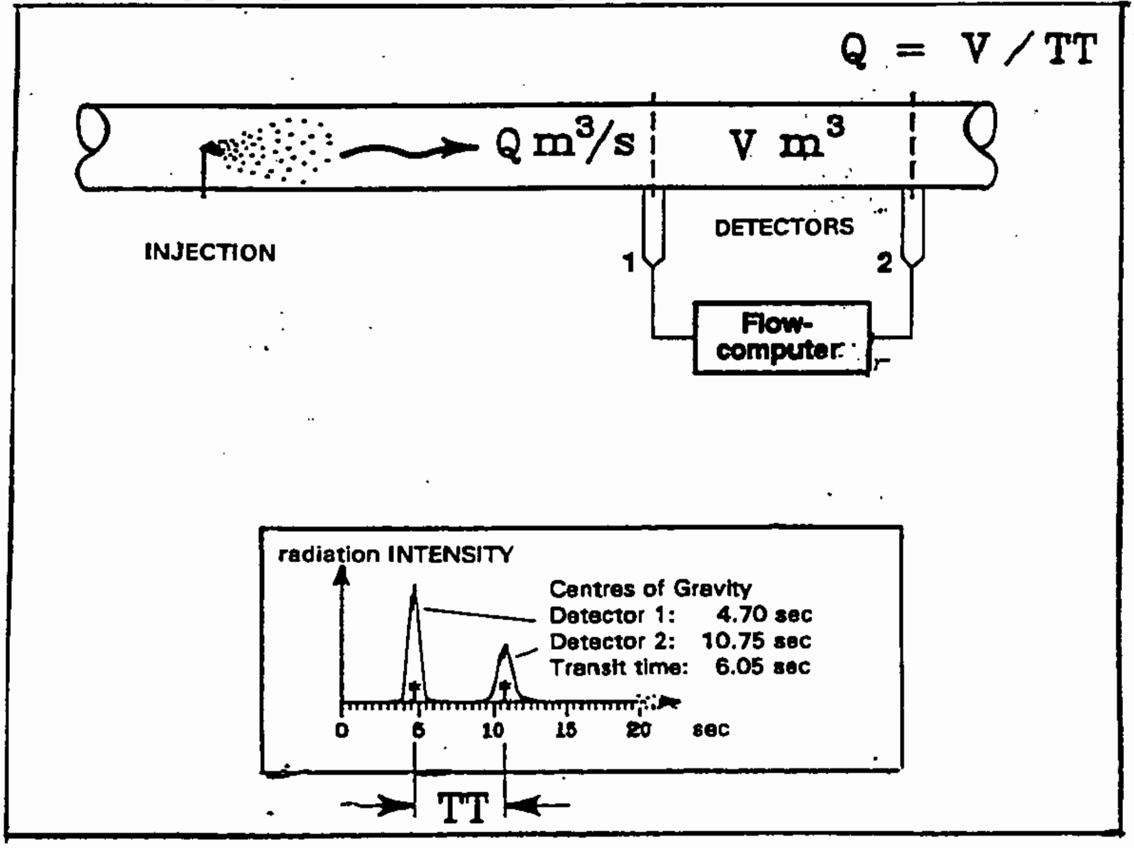


Figure 1: The principle of tracer measurement of flow by the transit time method.

Using the concentration versus time functions the mean value of the transit time from injection to each detector is calculated from which the mean transit time between 2 detectors is readily found. The linear velocity is found by simply dividing the distance between the detectors with the mean transit time.

Three detectors are normally used allowing for identification of flow variations during measurements. Such variation may occur even though the duration of each measurement is short, especially at low flow velocities. Distances between detectors are typically 25 - 50 meters with a total of 60 - 100 meters from the first to the last. The distance from the injection point to the first detector must be long enough to ensure mixing of the tracer over the full cross-section and depends of the possible presence of valves, bends etc. Normally 50 - 100 times the diameter of the pipe is required for optimum accuracy.

An example of actually recorded transit time functions is shown in figure 2.

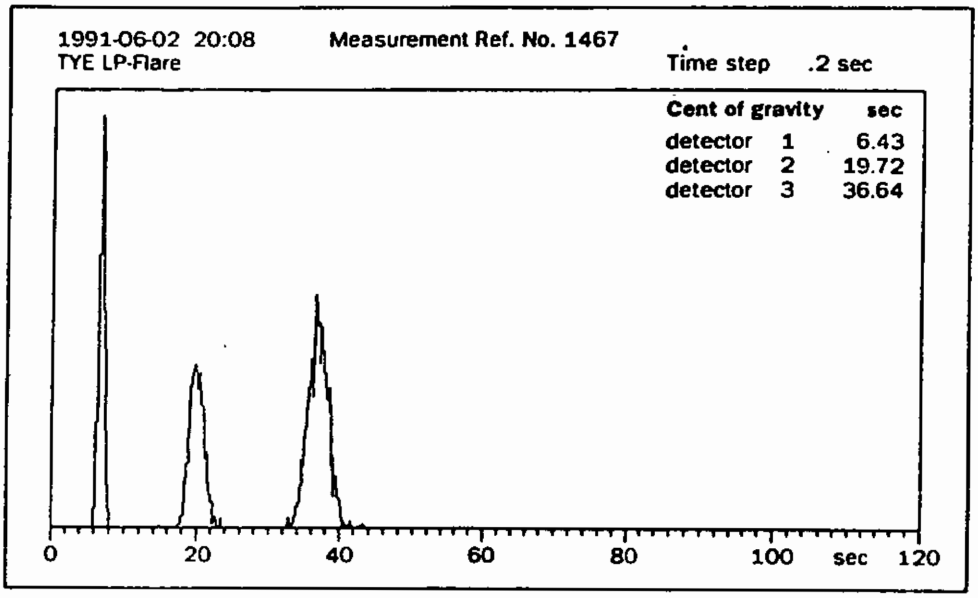


Figure 2: Recording of tracer concentration versus transit time

INSTRUMENTATION

The instrumentation for the gaseous tracer flare flow measurements consists of 3 units:

- an injection unit with tracer storage
- a package of 2 - 3 individually operated radiation detectors
- a control, supply and data registration unit including PC for on site data treatment.

A block diagram of the system is shown on figure 3.

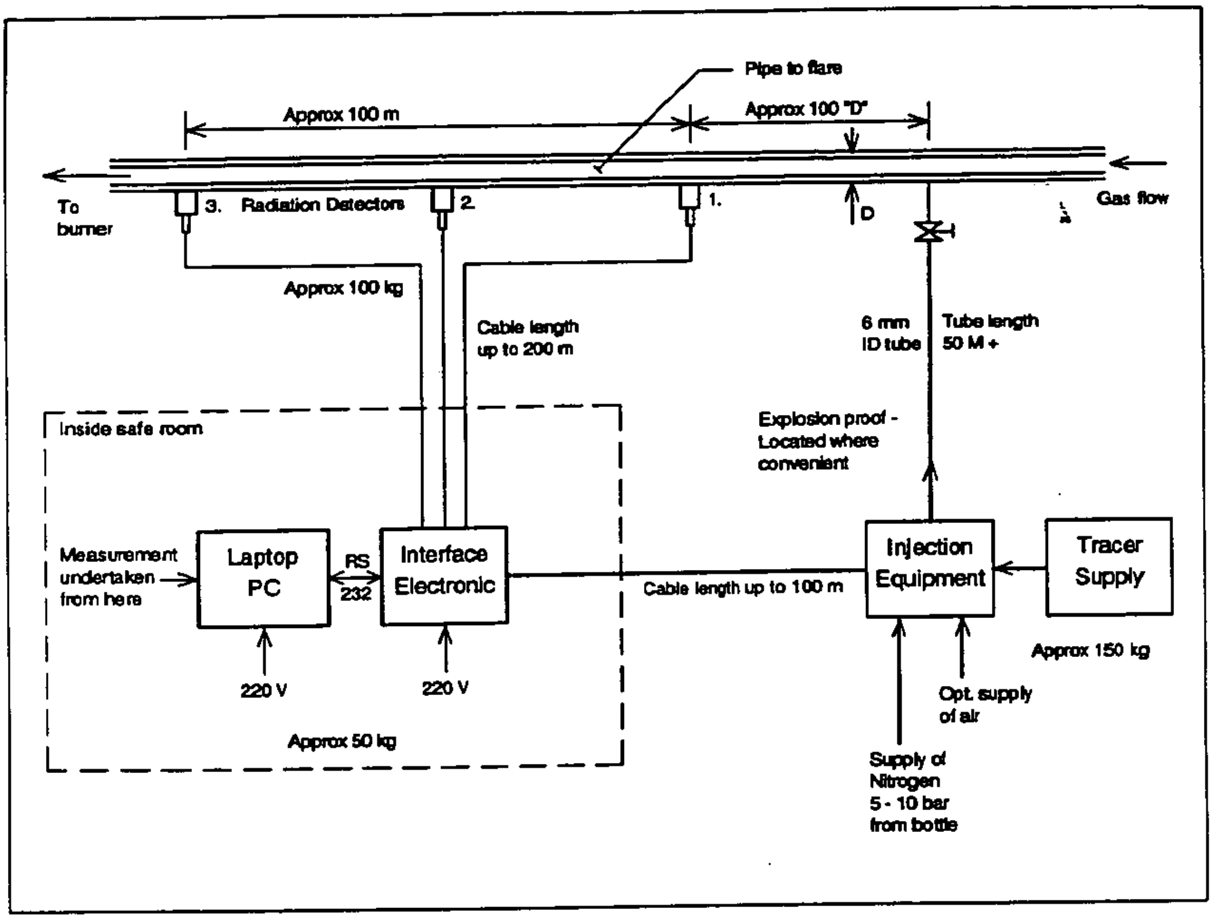


Figure 3: Block diagram of instrument set-up for gaseous tracer flow measurement

Injection unit

The injection unit undertakes injection of a short tracer pulse into the flare pipe. Our newest version was constructed during 1995 to meet increasing demands for fast and safe operation. The unit functions as follows:

The desired amount of tracer is metered off in a small chamber, which is subsequently flushed with a stream of nitrogen, through an injection tube with a length of up to 50 m and into the flare pipe, through a suitable inlet.

The flow and maximum pressure of nitrogen is adjustable to ensure optimal injection at the particular conditions. Typically the injection flow is approx. 2 litres/sec. and the travel time less than a second. By continuing the nitrogen carrier flow for 1 to 3 seconds after the pulse has entered the pipe line, residual tracer in the geometry through which injection is carried out, is removed, thus avoiding a long tail on the tracer pulse caused by slowly entering the gas stream. A total of 5 to 10 litres are injected, which is totally insignificant compared to the flow measured.

The pulse duration is shorter than 0.05 seconds when the pulse leaves unit. Despite dispersion in up to 50 m of tube leading to the injection point, the broadening of the pulse is low compared to that caused by the dispersion in the flare pipe and will thus not degrade measurement accuracy significantly. However, for maximum accuracy and lowest tracer consumption, the injection tube should be kept as short as possible.

Depending upon the geometry of the available injection point, the velocity of the injection jet will typically be so high that impact mixing occurs and enhances the radial mixing, causing the necessary distance from injection point to first detector to be shorter. Under optimal conditions a mixing difference of less than 0.5%, corresponding to a far less error in the flow measurement, can be achieved within considerably less than 100 pipe diameters.

Tracer is kept in a lead shielded steel cylinder being able to hold 600 GBq of Krypton-85 tracer, which is sufficient for between 150 and 2000 single measurements. The tracer consumption depends strongly upon the flow being measured (consumption roughly proportional with flow) and geometry of injection point and pipe (considerable variation).

The injection unit operates unmanned and is remotely controlled through up to 100 m cable leading to the controller and data processing unit, located in a safe room. The tracer filling and injection processes are fully automated and supervised from the instrumentation in the safe room. The electrical parts of the injection unit, being limited to magnetic valves and cabling for these, are in explosion proof versions.

Radiation detectors

The radiation detectors are highly sensitive 2" sodium iodide scintillation detectors in pressure tight, explosion proof stainless steel housing. The detectors are equipped with lead collimators in order only to detect radiation from a narrow field in the longitudinal direction of the flow. They are readily mounted out side the flare pipes, e.g. by roping. Power is supplied from and data transmitted to the controller unit trough up to 200 meters of cables.

The radiation measured through the pipe wall is proportional to the tracer concentration in the pipe cross section at the detector.

Controller unit and data treatment

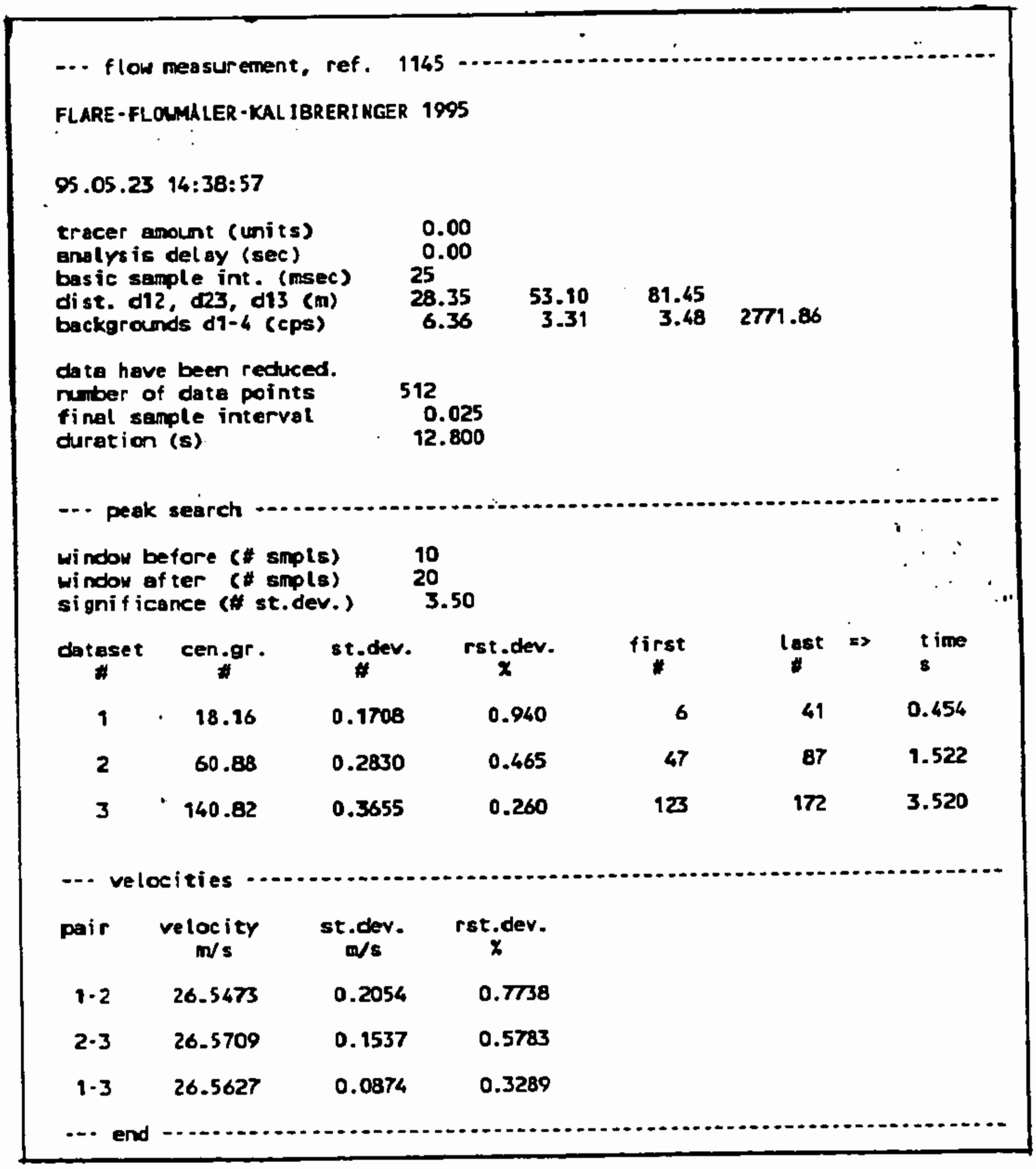
The controller unit is placed in a safe area with supply of power.

Injection is controlled by a PC.

Power supply for detectors and primary registration of data for radiation detection is performed by a dedicated data registration unit, which transfers data to the PC for further treatment.

The detectors measure tracer concentration with a sampling time suitable for getting sufficient time resolution in the concentration versus time function. Sampling times down to 0.025 second can be selected.

The mean transit time from injection to each of normally 3 detectors is calculated as the centre of gravity for the concentration versus time distribution. Simultaneously the standard deviation of the mean transit time is calculated. Transit time between detectors are calculated and from measured distances between the detector the linear velocities and their standard deviation are automatically determined. A computer printout as shown i figure 4 gives the measurements results immediately, allowing for on site preliminary assessment of results and decision about further measurements.



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--- flow measurement, ref.  1145 -----------------------------------------------

FLARE-FLOWMÅLER-KALIBRERINGER 1995


95.05.23 14:38:57

tracer amount (units)          0.00
analysis delay (sec)           0.00
basic sample int. (msec)      25
dist. d12, d23, d13 (m)       28.35       53.10       81.45
backgrounds d1-4 (cps)         6.36        3.31        3.48    2771.86

data have been reduced.
number of data points         512
final sample interval           0.025
duration (s)                   12.800


--- peak search ----------------------------------------------------------------

window before (# smpls)        10
window after  (# smpls)        20
significance (# st.dev.)        3.50

dataset    cen.gr.      st.dev.     rst.dev.       first        last  =>    time
   #          #            #           %             #            #          s

   1        18.16       0.1708       0.940           6           41        0.454

   2        60.88       0.2830       0.465          47           87        1.522

   3       140.82       0.3655       0.260         123          172        3.520


--- velocities -----------------------------------------------------------------

pair     velocity     st.dev.     rst.dev.
            m/s          m/s          %

 1-2     26.5473      0.2054      0.7738

 2-3     26.5709      0.1537      0.5783

 1-3     26.5627      0.0874      0.3289

--- end ------------------------------------------------------------------------
```

Figure 4: Computer print out of tracer velocity measurements.

CONTROL AND CALIBRATION EXPERIENCE

Ever since 1983 yearly calibrations have been made on 4 flares on Danish offshore platforms. Measurements have also been made on Danish and Norwegian onshore gas treatment facilities and oil refineries.

The permanently installed flow meters controlled have been of the thermal, ultrasonic, and orifice types.

The gaseous tracer method performed by the FORCE Institute yields the linear flow velocity of the flare gas. Data for inner pipe diameter is available from the plant operators. Supplementary measurements of temperature, pressure, and density and/or moleweight are performed by plant operators or flow meter service operators.

The typical test procedure involves the following steps

- transport of equipment (ship) and personnel (helicopter) to platform
- arrange necessary working permit
- install injection unit at first injection site and detectors at measurement positions, measure distance between detectors
- install controller unit in safe area
- hook up cables and hoses
- test of instrumentation
- measurements at present calibration at various flow rates
- adjustment of metering system } may be repeated
- repeated measurements }
- install on next flare or ship equipment.

Normally one flare on a platform may be calibrated over two working days for optimum accuracy, but more flares on the same platform reduces the time for instrumental set-up. If the demands for accuracy is limited the number of measurements per flow rate may be limited both before and after adjustment of the meter, which will to some degree cut down time consumption.

For the highest flow rates each tracer measurement only lasts 15 seconds with a repetition frequency of less than 40 seconds thus limiting the amount of gas being flared during the measurement procedure.

DYNAMIC RANGE AND ACCURACY

The methods covers the full dynamic range of linear velocities from a few centimetres/second to over 100 meters/seconds with one and the same instrumental set-up. Only the amount of tracer used per injection is varied.

The main sources of error which define the accuracy are counting statistics in tracer concentration measurements, the dispersion of the tracer cloud in the flare gas stream, and the stationarity of the flow during measurements.

Under typical conditions and flow rates up to 50 meters/second the accuracy have been experienced to be considerably below ±0.5%.

At higher flow rates the dispersion of the tracer and the lower limit for time resolution of the concentration versus time distribution limits the accuracy to better than ±2%.

At lower velocities the unstationarity of the flow during measurements may set the limit. This possible effect in controlled using three detector and observation of any differences in the velocity determined from different pairs of detectors.

The geometry of the injection point is very important. Thus, injection into a flare drum should be avoided as it will increase the dispersion and dilution of the tracer gas and thereby decrease the accuracy unless prohibitively large amounts of tracer are used to compensate.

Repeated measurements, which is feasible due to the efficiency of the method and the equipment, are most often applied, and improve the overall accuracy, when optimum performance is required.

SAFETY

The choice of tracer gas for the measurements is Krypton-85. It has a long half-life so that it can be stored for application when needed. In is a noble gas which is chemically inactive giving a low radio toxicity as it is readily removed in case of accidental contamination.

Transport and handling of the radioactivity follows internationally accepted regulations and is conducted be personnel from FORCE Institute under the local national radiation health authorities.

The amounts of isotope used is limited due to application of highly sensitivity radiation detectors. The amounts cause no significant radiation exposure to platform personnel, and normally no rope off is required when performing the tracers flow measurements. Even at peak tracer concentration the radiation level at the pipe surface is less than 1 - 2% of the accepted dose rate of 60 µSv/h, which is accepted just out side roped off areas during x-ray testing of weldings. The radiation detectors used on the other hand are so sensitive, that x-ray testing should not be performed within 200 meters from any detector.

Krypton-85 is produced from nuclear waste by concentrating in reprocessing. If not reprocessed and used it would be discharged to the atmosphere anyway, and the amount used in flare gas flow measurements are thus totally insignificant compared to the amount being present in the global environment.

CONCLUSION

The use of tracer methods for flare gas flow measurements has proved in many years of practice to be an efficient method for flow meter control and calibration and flow assessment. The measurements are performed in situ under normal conditions without interrupting the production.

The dynamic range and the accuracy obtained have been shown to be of great practical value, and the measurements are fast, reliable and safe.

REFERENCES

/1/ International standard ISO 4053/IV, "Measurements of gas flows in conduits - Part IV: Transit time method using radioactive tracers"