CALORIFIC VALUE MEASUREMENT WITH HONEYWELL HVT - 100

by

I Bates and T Davies
Total Oil Marine plc

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IAN P. BATES

TOTAL OIL MARINE PLC, ABERDEEN

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1. INTRODUCTION

This paper describes the requirement to replace the Continuous Recording Calorimeter with a more reliable and accurate instrument for the purposes of Fiscal Calorific Value measurement of Natural Gas.

The options considered are reviewed and particular attention is given to the instrument selected, detailing its evaluation and final installation.

The instrument selected was the 'Heating Value Transmitter' manufactured by Honeywell.

1.1 The Installation

Natural gas processed by the St. Fergus Terminal is transferred to the British Gas site for nationwide distribution. This transfer takes place through two parallel pipes, each metered by separate metering stations termed Phase I and Phase II.

Revenue from British Gas is based on energy, therefore the calorific value (CV) of the gas flowing through both pipes is required to be measured and transmitted to the flow computers for heat flow computation.

The measurement of the sales gas gross calorific value has been performed by 4 continuous recording calorimeters, two units installed on each Phase in a closely controlled and monitored air conditioned room. A sample line runs from the metering station pipe header to both calorimeters, allowing a continuous analysis of the same gas sample.

1.2 Existing Calorimeters

Since gas first flowed at St. Fergus calorific value has been measured by the industry accepted standard device - the continuous recording calorimeter, manufactured by Cutler Hammer.

As these units were designed in the 1930's their construction is almost entirely of moving mechanical parts, many operating in direct contact with water. The units display a sensitivity to ambient temperature and must therefore be operated in a closely controlled environment at all times. The moving parts are subject to wear which results in instrument drift.

As with any piece of analysis equipment, the manufacturers quote an expected accuracy. In the case of the Cutler Hammer calorimeter this is ± 0.5%, corresponding to ± 0.20 MJ/sm^3

Normal operation calls for close monitoring of instrument performance on a daily basis, this includes checks relating to the air conditioning systems. The accuracy of measurement is verified on a weekly basis by placing each unit on standby in turn and passing certified test gases through the device under test. A close examination of the unit is also required at this stage.

Planned maintenance is required on each calorimeter every three months by taking the units out of service in rotation. In addition to routine maintenance, the mechanical and electrical performance has to be rigorously tested. If unacceptable wear is found, the instrument is stripped and the area of wear located and remedied. This operation may take several days and large quantities of spares have to be stocked so that there are no unnecessary delays due to shortages.

During this maintenance period no standby unit is available. If a fault develops with the duty calorimeter, a preset CV may be required which usually calls for corrections to production totals to be made.

2.0 THE REQUIREMENT FOR A REPLACEMENT

2.1 The Continuous Recording Calorimeters gave rise to the following areas of concern.

a) Obsolescence

Cutler Hammer no longer manufacture complete calorimeters or spares. Although spares are available their quality is often poor. This has resulted in a programme of refurbishment being carried out, replacing critical items with specially manufactured items followed by accurate alignment.

b) Reliability

In addition to instrument drift detected by close monitoring, operational problems have been experienced due to a number of failures of the calorimeters. Occasionally, a calorimeter would trip while on-line, completely unexpectedly, rigorous examination revealing no apparent fault. These failures were subsequently traced to porous castings.

c) Accuracy

As gas revenue is directly proportional to measured calorific value, we are obliged to operate the calorimeters at the best accuracy level achievable. However, this level is limited by relative inadequacies in the design, materials used and manufacturing tolerances employed in these rather antiquated devices.

Although the calorimeters may be calibrated accurately at a single point it is rather difficult to maintain the accuracy at the various CVs encountered when in operation.

These units are sensitive to changes in ambient temperature, if faults develop with the air conditioning system, inaccurate measurement will result. To a lesser extent the calorimeters are affected by changes in atmospheric pressure, this results in misleading calibration results if attempted during periods of extreme barometic pressure.

The units are slow to respond to transients and may therefore not follow CV excursions correctly. The slow response time is a considerable problem when relighting following a shutdown. During this operation the calorimeters are extremely temperamental.

d) Maintenance

Due to the high level of manual monitoring and frequent intervention required in addition to the lengthy planned maintenance periods, the calorimeters are unreasonably dependent on skilled manpower. In view of the obligation to maintain accurate measurement at all times, little can be done to reduce this manpower requirement.

As the calorimeters become older and spares become rarer, the maintenance problems will increase with a corresponding deterioration in reliability and accuracy.

e) New Technology

It is now widely recognised that significant improvements in metering accuracy and reliability have been achieved through the widespread adoption of digital flow computers and largely solid state instrumentation, such as modern differential pressure transmitters and densitometers. Essentially moving parts have been either reduced to an absolute minimum or eliminated entirely in order to provide these advances.

Rather than continuing with obsolete equipment, it has been our policy to appraise devices which employ new technology.

3.0 REPLACEMENT OPTIONS

3.1 Several devices are available to measure the calorific value of natural gas. These devices may be categorised into three types.

a) Calorimetry methods which measure the heat released by the combustion of a metered volume of gas. The Cutler Hammer calorimeter was an example of this type.

b) Gas analysis methods which determine the calorific value by calculation from an analysis of the concentrations of individual components in the natural gas mixture. Instruments which may be included in this classification are: gas chromatographs, and spectrometers.

c) Inferred measurement methods which calculate the calorific value by measurement of a parameter which is related to the calorific value. Examples of this type are the Honeywell HVT-100 and the Therm-Titrator.

3.2 Each of these options was considered, but we required that items to be short listed should have already been proven in service as we could not evaluate all possibilities.

In the UK sector of the North Sea, Operators have considered the gas chromatograph as a suitable replacement to the continuous recording calorimeter and this device has gained acceptance as a point of sale instrument.

The Honeywell HVT-100 has received good reports and is widely used in the USA.

The gas chromatograph and HVT-100 are now discussed in detail.

3.3 Gas Chromatograph

3.3.1 Advantages

a) Already accepted for Point of sale measurement in UK.

b) A fundamental advantage of using gas chromatography is that additional parameters such as relative density and compressibility may be calculated and used in metering calculations, reducing the overall number of instruments required. Special air conditioned rooms are not required, further simplifying the installation.
However, as Operator of a large gas transportation system, we have considerable experience in the use of gas chromatographs, both in the laboratory environment and offshore on MCP01 where on-line GCs are used.

3.3.2 For on line use at St. Fergus the following disadvantages arise.

a) The nature of Frigg gas does not allow a simple analysis of light carbon components due to the long tail of heavy components.

In order to allow an accurate analysis and subsequent determination of calorific value a protracted cycle time would be required. In addition, the type of chromatograph to perform this analysis on-line has not yet been sufficiently developed.

b) Even if accuracy were to be compromised, a typical cycle time for the evaluation of an updated calorific value would take a minimum of 10 minutes and this would present problems in monitoring gas quality, as a continuous output will be required for control purposes if blending/nitrogen injection is to be performed efficiently.

c) The detection of unexpected components may result in large errors.

d) The chromatography columns are subject to contamination and associated inaccuracy.

3.4 Honeywell HVT-100

3.4.1 Advantages

The HVT-100 had good reports from other organisations and showed promise in the following areas:

a) The manufacturers specification offers good accuracy under our process conditions.

b) The unit is self calibrating and is designed to operate with minimal intervention.

c) The minimum amount of moving parts are used which promises good reliability. The design is microprocessor based with modern self diagnostic routines to aid rapid fault finding. A modular construction is employed which should allow quick exchange of faulty components.

d) The HVT provides a continuous output of measured calorific value and a fast response time is offered.

e) Unlike a conventional calorimeter the HVT is designed to tolerate variations in ambient temperature and would therefore maintain accurate measurement if the air conditioning system for the calorimetry room were to fail.

3.4.2 Disadvantages

a) Not accepted for point of sale measurement in UK at time of investigation.

b) A Specific Gravity analyser is required in addition to the HVT-100 for heat flow computation to Fiscal Standards.

3.5 Following a two week familiarisation period with a unit on site, the HVT-100 was selected as the device most likely to be able to demonstrate a worthwhile improvement in accuracy and large savings in maintenance costs over the existing calorimeters.

4.0 HVT-100

4.1 Principle of Operation for the HVT-100

The HVT-100 employs the well recognised principle, that for the gases in the paraffin (alkane) series, there is a direct relationship between the air to fuel ratio required to achieve stoichiometric combustion and the calorific value of the gas. This relationship also holds for a mixture of gases such as present in natural gas (Fig 1).

The air to fuel ratio is determined by a rotary mixing valve, where the rotational speed influences the ratio.

Mixed gas and air is then burnt in a combustion chamber where stoichiometric combustion is determined by monitoring the exhaust gas with a zirconium oxide sensor. This sensor detects the presence of oxygen in the exhaust gas and provides an output to the microprocessor controller which controls the rotational speed of the mixing valve. These components form a closed loop control system operating in the following manner to maintain stoichiometric combustion (Fig 2).

The zirconium probe develops its greatest output voltage when the oxygen content in the exhaust gas is at its lowest level. As the air to fuel ratio is adjusted towards a leaner mixture, the sensors output decreases until a point is reached where it drops sharply, in a stepped fashion, to a level at which any further increase in the air would cause the output to taper off into a nerstian region (Fig 3). The step response in the sensors output marks the period during which stoichiometric combustion occurs at the burner. The speed of rotation of the mixing valve is adjusted in accordance with the oxygen sensor output and the measured rate of rotation is related to the calorific value. The calorific value is in turn shown on a digital display on the front panel and also scaled for output as a 4-20 mA signal.

Self calibration is achieved by automatically switching from sample gas to a calibration gas such as methane. The HVT measures the CV of the calibration gas and then adjusts itself to measure the known value of the calibration gas input by the user. The auto-calibration interval is also preset by the user.

4.2 Installation

An HVT-100 was purchased for evaluation and installed in the Phase II calorimeter room and connected in parallel with the No. 2 calorimeter so that both the HVT and the calorimeter receive the same sample gas without affecting calorimeter operation.

5.0 EVALUATION TEST

5.1 Evaluation Test Programme

An evaluation test programme was drawn up to include tests which allowed an assessment of the HVT's suitability for accurate measurement of natural gas calorific value.

If favourable results were obtained then the test findings would be used as a basis for gaining approval for the HVT-100.

Test Criteria

The test unit, when compared to the existing calorimeters under the same operating conditions, should prove to be a worthwhile improvement in the following areas:

a) Accuracy and repeatability
b) Sensitivity to environmental conditions
c) Response time
d) Stability of output
e) Reliability
f) Maintenance requirement
g) Availability of spare parts.

5.2 Accuracy and Repeatability

5.2.1 Accuracy

In order to assess the accuracy of the HVT-100 under operating conditions, the unit was tested using a number of specially formulated gases which had been analysed and certified by the Gas & Oil Measurement Branch of Department of Energy, Wigston.

The test gas mixtures specified were chosen to represent the range of natural gas mixtures likely to be processed as St Fergus.

Gross calorific values for each test gas were calculated in accordance with ISO 6976 based on the certified gas analysis provided by Department of Energy.

5.2.2 Method

The tests were performed with the HVT-100 and the stand-by Cutler Hammer calorimeter piped in parallel, so that both instruments received the same gas test. This allowed a direct comparison to be made under normal operating conditions.

The Cutler Hammer CV was read from the on-line flow computer displays and the HVT CV was taken from the instruments digital display.

5.2.3 Results

HVT-100	Results within ±0.05MJ/sm^3 for gases likely to be measured at St Fergus. The synthetic associated gas was within 0.10 MJ/sm^3
CH Calorimeter	Results within ±0.05MJ/sm^3 except the synthetic associated gas: ±0.15MJ/sm^3

5.3 Sensitivity to Environmental Conditions

This section may be split into two main areas: sensitivity to changes in ambient temperature and secondly, atmospheric pressure.

5.3.1 Ambient Temperature

The existing Cutler Hammer calorimeters are recognised as being sensitive to ambient temperature and for this reason are required to operate in an air conditioned room having a closely controlled air temperature.

As the HVT was installed in the same room it would only have been possible to alter the air temperature if the calorimeters had not been operating for some period during the evaluation test. Unfortunately Phase II was required to flow gas continually during this period and so ambient temperature effects could not be checked.

However, the HVT-100 was designed from the outset to operate in the open air and this would indicate a degree of insensitivity to ambient temperature.

This has been confirmed by other organisations carrying out similar evaluation tests.

5.3.2 Atmospheric Pressure

The Cutler Hammer calorimeters at St Fergus are known to display a certain degree of sensitivity to atmospheric pressure.

In order to assess any atmospheric pressure effect on the HVT-100,an analysis of the auto calibration results was made.
A sensitivity to atmospheric pressure changes should result in a deviation from the expected calibration results.

Barometric pressure readings were taken from continuous barograph charts (kindly loaned by British Gas St Fergus).

The effect of changing atmospheric pressure on the HVT is shown graphically in graphs A-E. These graphs analyse data for 5 days chosen to give a variety of barometric patterns. These included i) Steady barometric pressure. ii) Steadily falling barometric pressure. iii) Steadily rising barometric pressure. iv) A pressure peak and v) A pressure trough. The measured CV data is for certified high purity methane (37.77 MJ/sm3) using a 2 hour autocalibration period.

Each graph consists of three parts:

Top:	Tabulated calibration gas measured CV and corresponding barometric pressure at 2 hour intervals. Calculated values are CV error (assuming 37.77 MJ/sm3 is correct) and % change in barometric pressure since the last calibration.
Middle:	Plot of daily barometric pressure variation.
Bottom:	Plot of calculated values from table.

5.3.3 Findings

Graphs A and B show that there is a definite proportional linear relationship between CV error and change in barometric pressure. The relationship can be roughly defined as:

$$\frac{CV}{\Delta P} = 1.0 \quad \frac{MJ/sm^3}{\text{in Hg}}$$

If all drift is due to the barometric pressure change and fits the above relationship then:

$$\int_{t = To}^{t = T} d(CV) = \int_{t = To}^{t = T} KdP\ dt$$

If pressure variation is assumed to be linear between any two calibrations then due to the cyclical nature of barometric pressure it would be expected that:

$$\int_{t = To}^{t = T} d(CV)dt \rightarrow 0 \quad \text{as } (T - To) \rightarrow \infty$$

i.e. long term bias error due to atmospheric pressure should tend to zero over a long period if the above assumptions are correct.

Taking the complete test period for the 2 hour calibration data from 15 October 1987 to 7 January 1988 (spanning more than 600 calibrations); calculation gives average methane measured CV = 37.763.

Based on the assumption that pressure varies linearly with time and that measured CV error will be zero immediately following a calibration.

$$\text{Mean CV error} = \frac{37.763 - 37.77}{2} = -0.0035\ \text{MJ/sm3}$$

Since calibration gas CV is certified as 37.77 MJ/sm^3 an uncertainty of ± 0.005 MJ/sm^3 is implied.

Therefore long term bias error in CV is within the tolerance of the calibration gas. It can be confidentially stated that there was no detectable long term bias error introduced into CV measurement due to atmospheric pressure changes when using the HVT with a 2 hour calibration period.

SYMBOLS

T, t = Time

dP = Change in barometric pressure over time dt

K = Proportionality constant

d(CV) = Change in measured calibration gas CV over time dt.

AUTOMATIC CALIBRATION

5.3.4 The HVT is designed to operate using regular automatic calibration to compensate for any measurement drift. The calibration interval may be set by the user between 10 minutes and 4 hours.

In order to assess the effect of different intervals on the accuracy of CV measurement, the HVT was operated on normal sample gas with calibration intervals of 4 hours, 2 hours and 1 hour.

During each calibration cycle the HVT samples the calibration gas with normal sample gas isolated. The calibration gas is measured for a 30 second period and if stability criteria are passed, the result given on the printout is the mean value over the period.

Ideally, this result should be identical to the known calibration gas value, but if this is not the case the HVT will automatically realign itself to remove the measured error before returning to normal sample gas.

An analysis of these reported errors will allow an impression to be gained of the general accuracy of the HVT at different calibration intervals, allowing the optimum calibration interval to be set.

5.3.5 Findings

If the HVT-100 does not drift or display any error then the reported values at each auto-calibration test should always match the calibration gas value held in the HVT as a fixed parameter.

The calibration gas used throughout was high purity methane certified at 100% by Department of Energy, ISO 6976 gives a CV of 37.77 MJ/SM^3. Thus ideal results should be a straight line at this value with a standard deviation of 0.

4 Hour Interval

The overall average result over 45 days is 37.760 MJ/SM^3 with a mean std. deviation of 0.0300 MJ/SM^3. This would infer a slight under-registration of calorific value by 0.01 MJ/SM^3 over this period if constant CV gas had been sampled. Although the error encountered in measuring sample gas may be different to this value as one represents a pure gas and the other a mixture, the small magnitude of this error is very impressive.

2 Hour Interval

The overall average result for 94 days was 37.764 MJ/SM^3 with a mean standard deviation of 0.0308 MJ/SM^3. Thus this calibration interval gives slightly better results than a 4 hour interval.

This result is most impressive and shows that a 2 hour calibration interval maintains accurate measurement when operating on sample gas and is highly effective in reducing instrument drift.

1 Hour Interval

This test duration was limited to a period of one week due to the high calibration gas consumption rate.

The overall average obtained was 37.754 MJ/SM^3 with a mean standard deviation of 0.0226 MJ/SM^3.

Although this interval resulted in less scatter than the larger intervals, the overall average was slightly poorer. Thus the results from this brief test indicate that there is no benefit to be gained by using a 1 hour calibration interval.

5.4 Response Time

5.4.1 Method

The response time of the HVT-100 to changes in sample gas calorific value has been compared to an existing Cutler Hammer calorimeter using test gases.

The gas inlet pipework to the calorimeters allows gas to be instantaneously switched between normal sample gas and a test gas, or between two test gases. This operation is performed using manually operated valves.

5.4.2 Findings

The HVT was found to respond immediately to a step change in gas calorific value. The trend in all cases was near critical damping whether in response to an increase or decrease in CV. No sign of overshoot was noted, the initial response stopping just short of the final oscillating trend.

The results may be summarised as follows:

Time taken to reach 98.5% of step change in CV :20 sec per MJ/SM^3

Additional time taken to attain final 1.5% of step change :60 seconds

In contrast to the HVT-100 the C.H. calorimeter has a far poorer response time.

Switching between test gases which differ by 4MJ/SM^3, first response does not occur for over 4 minutes.

In this case, HVT-100 would take 2 minutes 20 seconds.

Start-up

Following a shutdown the HVT-100 takes approximately 4 minutes before the output is restored. The start-up procedure is very simple: the sample gas supply is turned on and the HVT front panel ON/OFF button is pressed. No output is provided during the 4 minute stabilisation period, the output is restored as a step change.

Following a start-up the CH calorimeters are usually allowed to stabilise for a minimum of two hours before being considered for duty.

5.5 STABILITY OF OUTPUT

5.5.1 The Cutler-Hammer calorimeters tend to display a slightly oscillating output under steady input conditions. This trend is usually exaggerated by the length of service between rebuilds and is thought to be caused by wear resulting in small degrees of misalignment of the rotating parts. A limit has been set as to the maximum acceptable oscillation of 0.10 MJ/SM^3 peak to peak. Although an oscillation should not lead to poorer overall accuracy, as the mean result over the course of a day is the same for a constant output, the calorimeter instantaneous maximum and minimum values may not be acceptable. This is due to both duty standby calorimeters being constantly monitored for a difference in measured value, if one reads a maximum and the other reads a minimum the differential alarm may be raised although the measured mean values are correct.

The HVT-100 also displays an oscillating trend. Amplitude is ±0.05 MJ/SM^3 with a time period of approximately 20 seconds.

The cause is the necessary variations is air/fuel rate in order to maintain stoichiometric combustion.

5.5.2 In order to check compatability with the flow computers, a spare flow micro-computer (869R) was linked to the HVT-100 via the analogue output.

A constant std volume flowrate was preset in the flow micro with CV as a measured variable. As energy and std volume flows are held for a 24 hour period, a daily average CV could be calculated and then compared with the HVT-100 internally generated daily average CV.

Very close agreement was found which indicates that the oscillation and the analogue converters do not degrade the daily energy totals.

Although not really necessary for our installation, we would prefer that the oscillations are reduced so that it is easier to interpret the measured CV at any instant.

It would seem that the most feasible way to reduce the amplitude of oscillation is to introduce a form of damping.

5.6 RELIABILITY

5.6.1 As the sample gas supplied to the HVT is essentially identical to both calorimeters on Phase II, a comparison may be made between reported daily average CVs.

5.6.2 Findings

An example of the results is shown in Graph F.

The HVT displayed daily averages are shown plotted against day number together with the Cutler-Hammer derived daily average taken from the flow computers.

The large swings in average CV are due to the effect of Piper/Tartan gas being injected into the pipeline in different quantities each day. This oil associated gas is much richer than the natural gas from the Frigg area.

The results from both instruments, essentially sampling the same gas, agree well, generally within 0.05MJ/SM^3 and appear to follow similar trends.

Following initial commissioning the HVT-100 ran reliably for the duration of the six month evaluation period.

5.7 MAINTENANCE REQUIREMENT

No regular maintenance of the HVT-100 is specified by the manufacturers. However, it is apparent that certain parameters require regular monitoring to prevent unexpected loss of information. These parameters are listed below:

a) Calibration Gas Bottle Pressure

The gas pressure within the calibration gas cylinder must be checked regularly and the cylinder changed before calibration gas is exhausted as this would result in the shutdown of the HVT.

b) Digital Printer Paper

As a considerable amount of important information is reported by the digital printer connected to the HVT, the amount of reserve paper in the printer should be monitored regularly in order to prevent the loss of reported daily averages, alarm states and auto-calibration results.

c) Analogue Output

The accuracy of the analogue output to the flow computers should be verified regularly in order to correct any drift which may occur. This may be performed quickly by comparing the HVT displayed value to the flow computer displayed value or by comparing the HVT daily average to the inferred flow computer average CV.

d) On Line Diagnostics

The on-line diagnostics routine should be run on a regular basis in order to monitor the state of internal parameters which greatly affect the operation of the HVT. If any of the reported parameters exceed predetermined levels then further action should be taken to investigate the fault.

e) It is recommended that a certified test gas other than methane is sampled by the HVT-100 on a regular basis in order to verify linearity. A binary gas such as the currently used methane/8% ethane mix would be suitable.

f) The most critical moving part in the HVT-100 is the rotary mixing valve which determines the air/fuel ratio. As wear may affect the unit's performance, this component should be inspected or replaced at annual intervals.

5.8 EVALUATION TEST - SUMMARY

The results may be summarised as follows:

a) Accuracy and Repeatability

The HVT-100 has proven to be highly accurate over a wide range of calorific values and will be able to operate accurately when sampling the gases likely to be processed at the terminal for the foreseeable future.

Both accuracy and repeatability were found to be well within the manufacturers specification which offers a significant gain over the existing calorimeters.

Accuracy is claimed to be ±0.10MJ/SM^3 over the range 33 to 41 MJ/SM^3.

The stated accuracy of the present CH calorimeters is ±0.20MJ/SM^3.

b) Sensitivity to Environmental Conditions

The HVT-100 displays a sensitivity to atmospheric pressure variations, but this is overcome by the automatic calibration feature. Tests have shown that a setting of 2 hourly auto-calibration interval is effective in maintaining accurate measurement.

c) Response

The response time to step changes in gas CV was found to be very quick at around 20 seconds per MJ/SM^3. This is a magnitude faster than the existing calorimeters and will allow transients to be followed much closer and also allow testing to be carried out quicker. Start-up is completed within 5 minutes.

d) Stability of Output

The Cutler-Hammer calorimeters tend to display an oscillating output under steady input conditions of up to 0.10MJ/SM^3 peak to peak. The HVT-100 also displays an oscillating trend of the same level but with a much shorter time period of approximately 20 seconds.

Testing revealed that this oscillation does not degrade the output signal in operation.

e) Reliability

Reliability of the HVT-100 has proven to be excellent during the long term test. Following commissioning the unit has operated with complete reliability with only minor interruptions due to external circumstances.

f) Maintenance Requirement

The Cutler-Hammer calorimeters require regular intervention to maintain accurate operation and planned maintenance involving laborious adjustment. Often a complete rebuild is found to be required.

In contrast, the HVT-100 requires no planned maintenance other than regular monitoring. This work is simplified by self diagnostic routines.

g) Availability of Spare Parts

This is an area of major concern for the existing CH calorimeters both in terms of long term availability and quality.

6.0 INSTALLATION AND COMMISSIONING

6.1 A report on the evaluation test was submitted to the Fiscal authorities, a non-objection to the use of the HVT was subsequently granted. An order for three additional HVT units was placed with Honeywell allowing installation to commence in January 1988.

Each HVT was installed alongside its operational calorimeter and prepared for service.

With a calorimeter providing the used calorific value signal the HVT was connected to the flow computers and assumed the role of comparison unit. Prior to acceptance, for Fiscal metering duty, each HVT was tested for a seven day period to establish correct operation and presence of any systematic errors.

In the final installation the HVT digital data is internally converted to an analogue output using a DAC. The 4-20 mA signal then passes via a 2 channel plotter to each of the six flow computers where the signal is converted to 0.2 - 1.0 v using 50 ohm resistors. The voltage is then converted to a digital signal within the computer using an ADC.

During the acceptance period the accuracy of analogue conversion was monitored and calorimeter trends compared with those generated by the HVT. In addition to the 2 hourly methane autocalibration, daily span checks were performed using a certified methane-ethane mixture.

6.2 Results

An offset of 0.02 - 0.04 MJ/sm^3 was found between the HVT internally generated daily average and the flow computer calculated average. This offset originates at the HVT DAC and as it is not possible to adjust the DAC to eliminate this it was necessary to adjust the HVT output scaling to compensate.

Other calibration and test results were will within tolerance.

One unit was found not to restart after a shutdown. The HVT will not restart until it detects a flame in the main burner, the unit apparently detects a flame by monitoring capacitance changes between the igniter plug and main burner earth due to flame ionisation. The problem was rectified by repositioning the igniter plug in the main burner using spacers.

On recommissioning the original HVT unit, problems were encountered in making the unit run reliably, positive and negative spikes were observed on the analogue output at unpredictable time intervals.
Faults found:

The dehydrator unit was found to be defective and was replaced.
The main fault could be reproduced by open circuiting the zirconium probe output. This caused the main burner assembly including the sensor and igniter plug to be replaced .
The power supply board showed signs of overheating and was returned to Honeywell for investigation.

The rotary valve showed signs of wear and was replaced. Although Honeywell advised that the rotary valve assembly is supplied 'factory set', it has been found that the analogue output oscillations may be reduced significantly by adjusting the valve disc position on the motor drive shaft.

6.3 All four units have now been accepted and are operating well. The four Continuous Reading Calorimeters have been decommissioned.

7. AREAS FOR IMPROVEMENT

a) The automatic calibration interval could be increased and accuracy further improved if automatic atmospheric pressure compensation were to be performed. The linear effect means that the addition of a simple pressure transducer is enough.

b) The digital to analogue output converter calibration is factory set but small offsets could be removed by including an adjustment pot.

c) The user manual is rather superficial and could be improved. Two areas where more information is definitely required is in setting up the rotary valve and igniter sensor.

d) During the commissioning period Honeywell support for the HVT-100 in respect of fully trained personnel was only available in the USA where most units are in service.

In order to maximise the performance of the HVT-100 Honeywell should consider action on the above points.

8. CONCLUSIONS

A survey of alternative devices lead to the Honeywell HVT-100 being selected as the most suitable replacement device for the aging Continuous Recording Calorimeter.

An evaluation over six months under actual operating conditions showed that the HVT-100 met the manufacturers specification and indeed performed better than the existing calorimeters.

The performance and reliability of the HVT-100 could be further improved by Honeywell. Regular maintenance details are required in order to avoid unexpected failures.

The HVT-100 units installed have performed with greater reliability, better accuracy and less maintenance than the replaced Cutler Hammer calorimeters.

9. FIGURES AND GRAPHS

Figs

1) Relationship between air/fuel ratio and calorific value.

2) HVT-100 schematic diagram

3) Zirconium probe output characteristic.

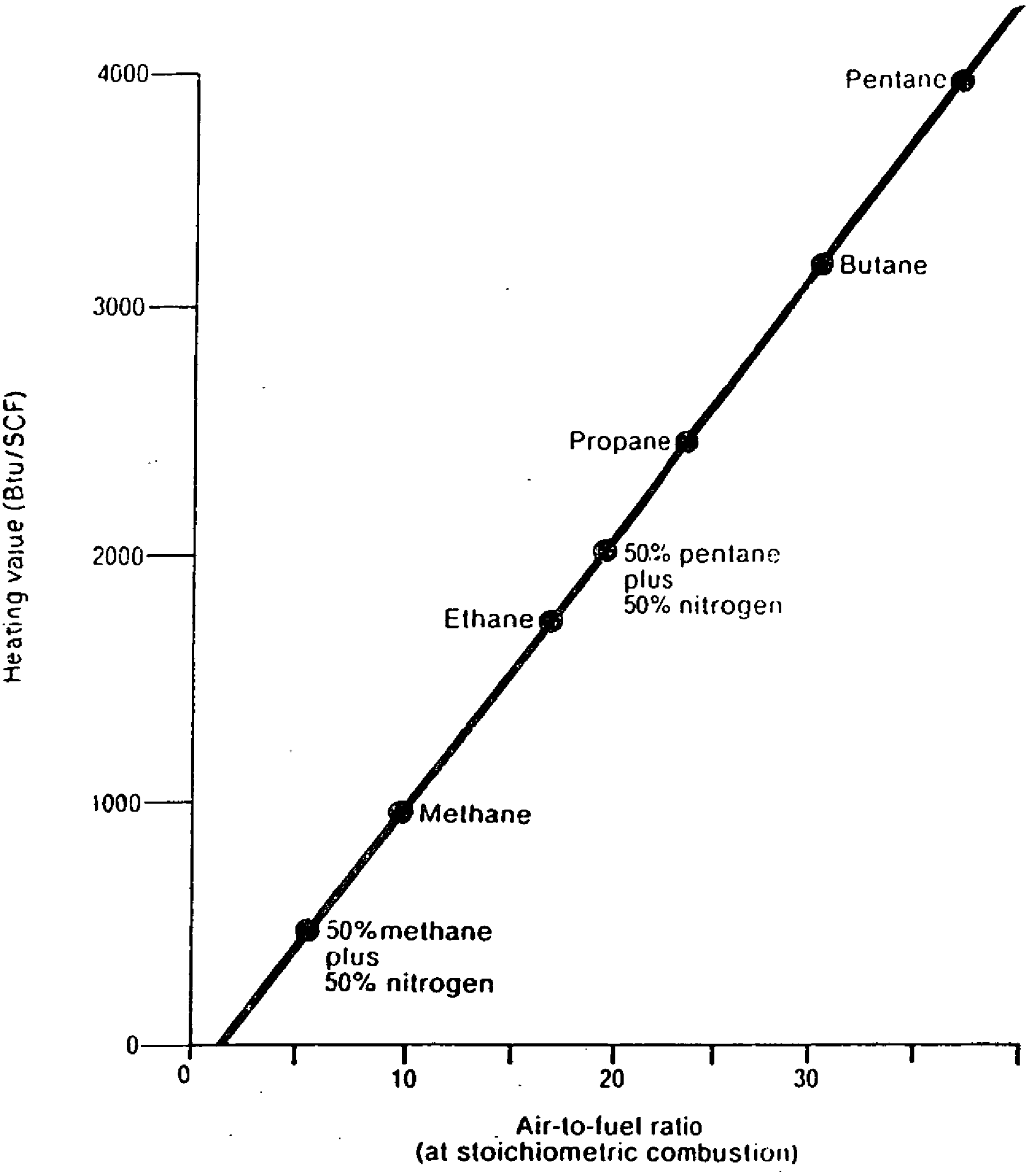
Graphs

a) Effect of steady barometric pressure
b) Effect of falling barometric pressure
c) Effect of rising barometric pressure
d) Effect of a barometric pressure peak
e) Effect of a barometric pressure trough
f) Comparison between HVT and calorimeter outputs

10. Acknowledgment

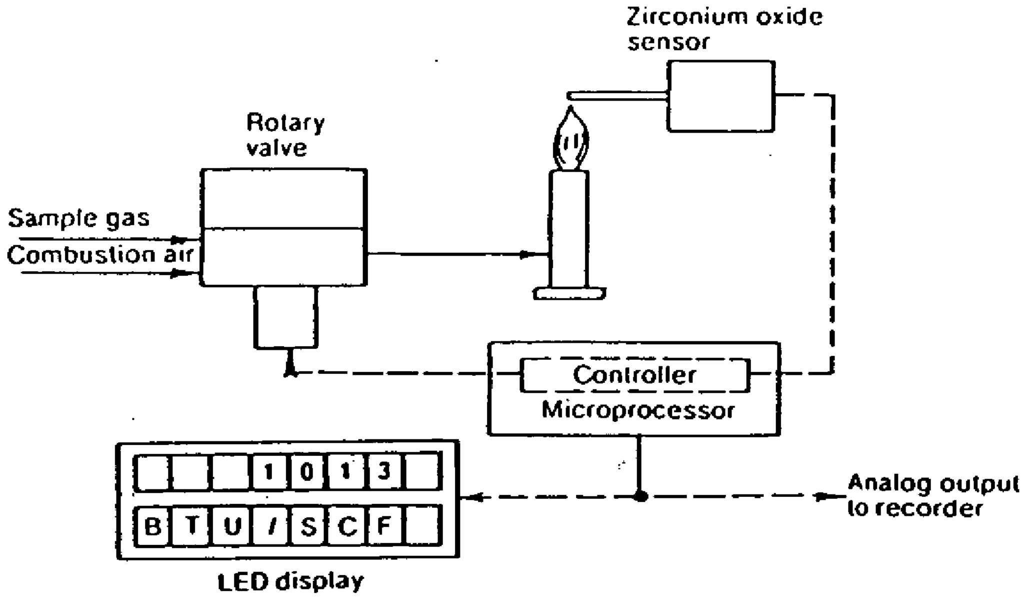
I would like to express my gratitude to Trevor Davis for his assistance in the preparation of this paper.

FIG 1.



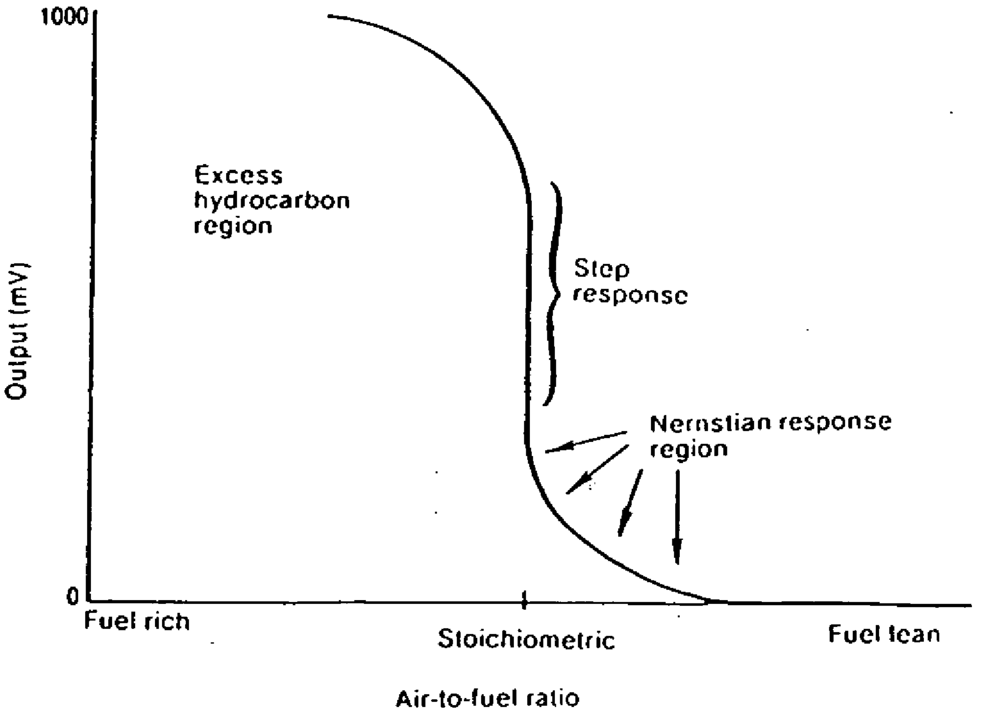
Heating value versus air-to-fuel ratios for paraffin series gases

FIG 2.



Basic operation of the HVT 100 Heating Value Transmitter

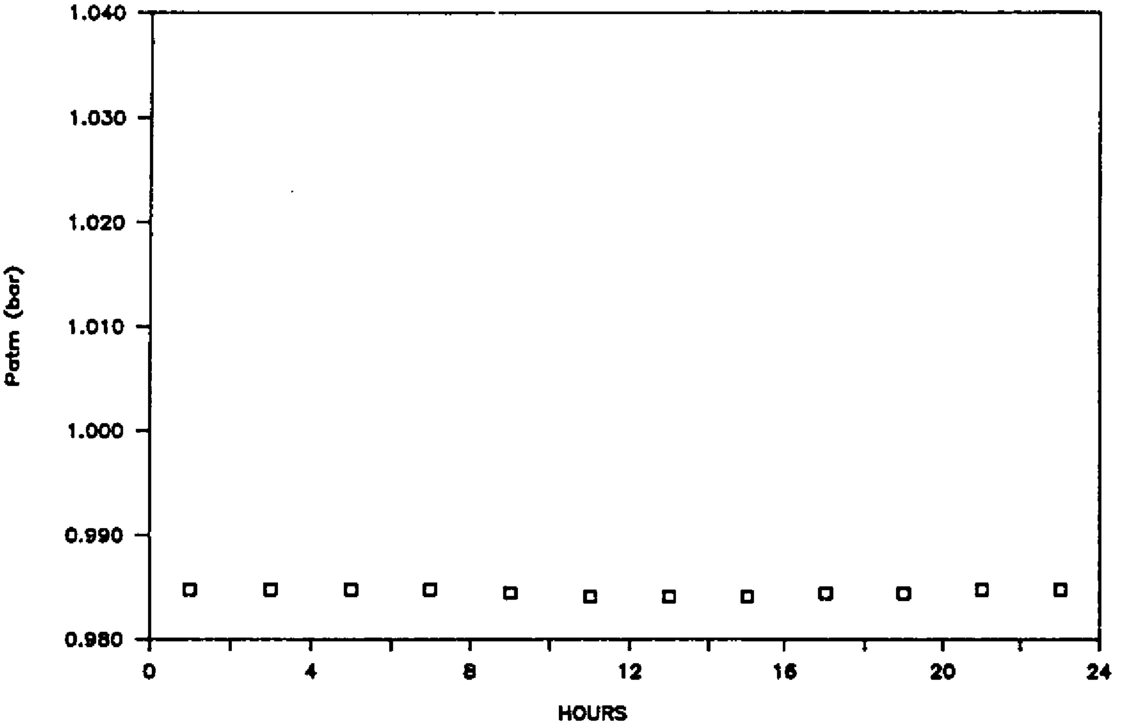
FIG 3.

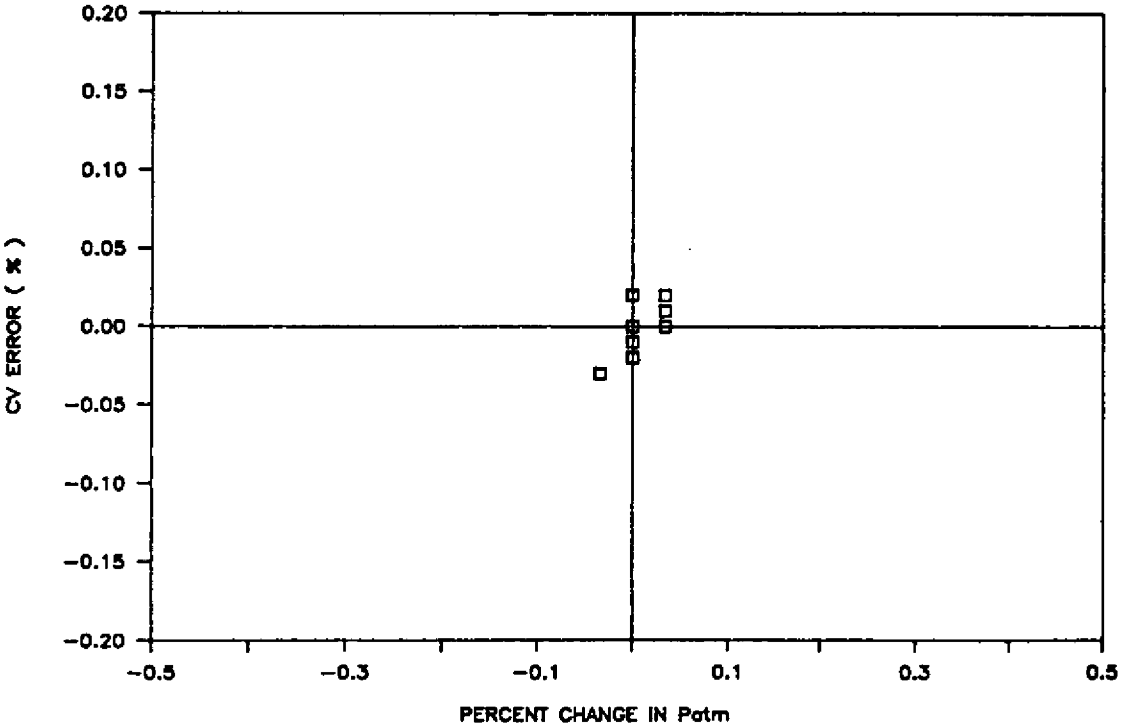


Performance of typical zirconium oxide sensor

DATE: SUN 19 DEC 1986 GRAPH A

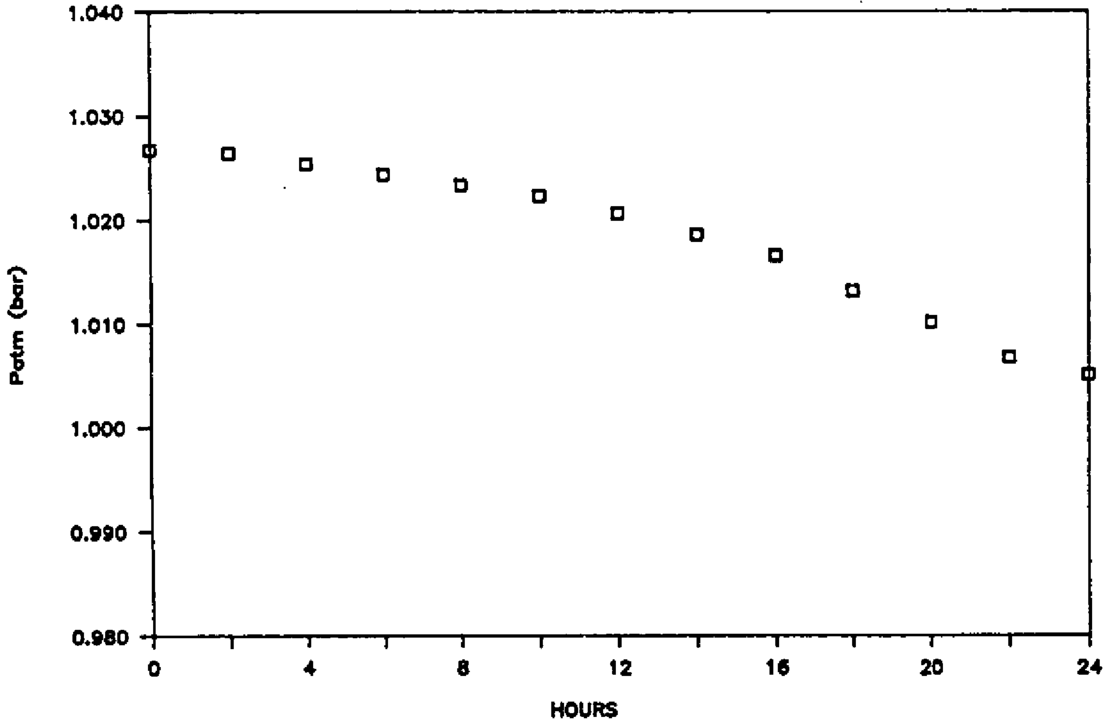
HOUR	BAROMETRIC PRESSURE Patm (bar)	CHANGE IN Patm (%)	MEASURED CALIBRATION GAS CV (MJ/sm3)	MEASURED CV ERROR (MJ/sm3)
-1	0.985			
1	0.985	0.000	37.75	-0.02
3	0.985	0.000	37.77	0.00
5	0.985	0.000	37.75	-0.02
7	0.985	0.000	37.79	0.02
9	0.984	-0.034	37.74	-0.03
11	0.984	-0.034	37.74	-0.03
13	0.984	0.000	37.79	0.02
15	0.984	0.000	37.76	-0.01
17	0.984	0.034	37.79	0.02
19	0.984	0.000	37.77	0.00
21	0.985	0.034	37.77	0.00
23	0.985	0.000	37.77	0.00
25	0.985	0.034	37.78	0.01

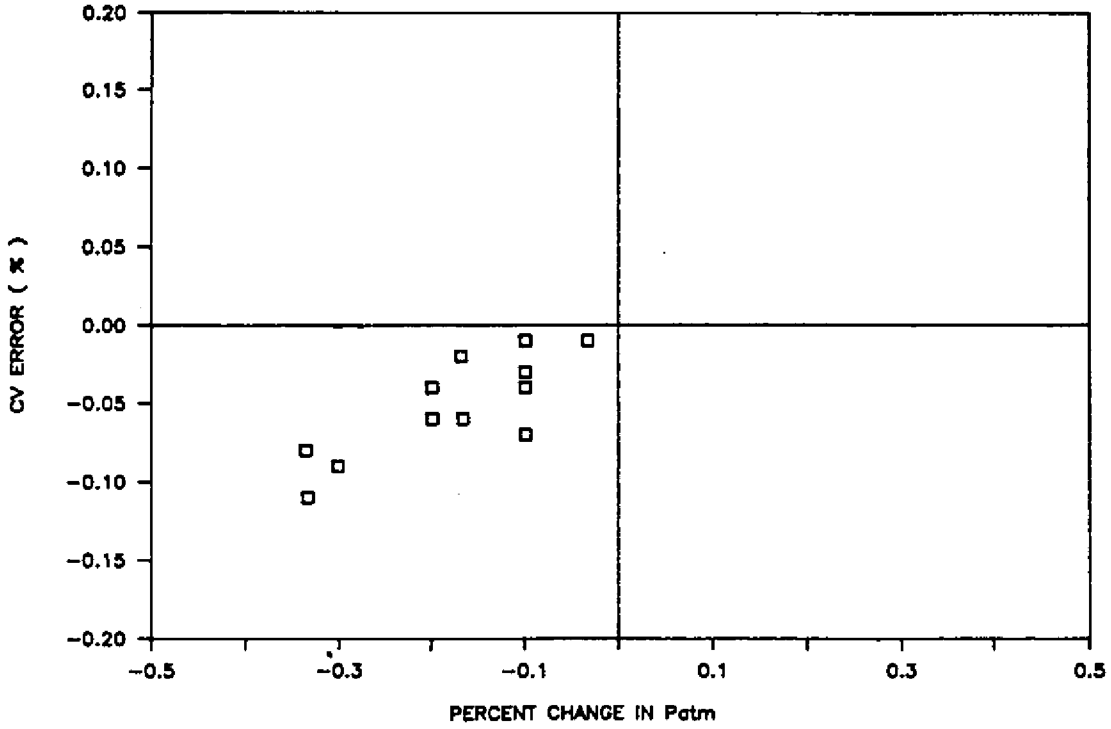




DATE: WED 24 DEC 1986 GRAPH B

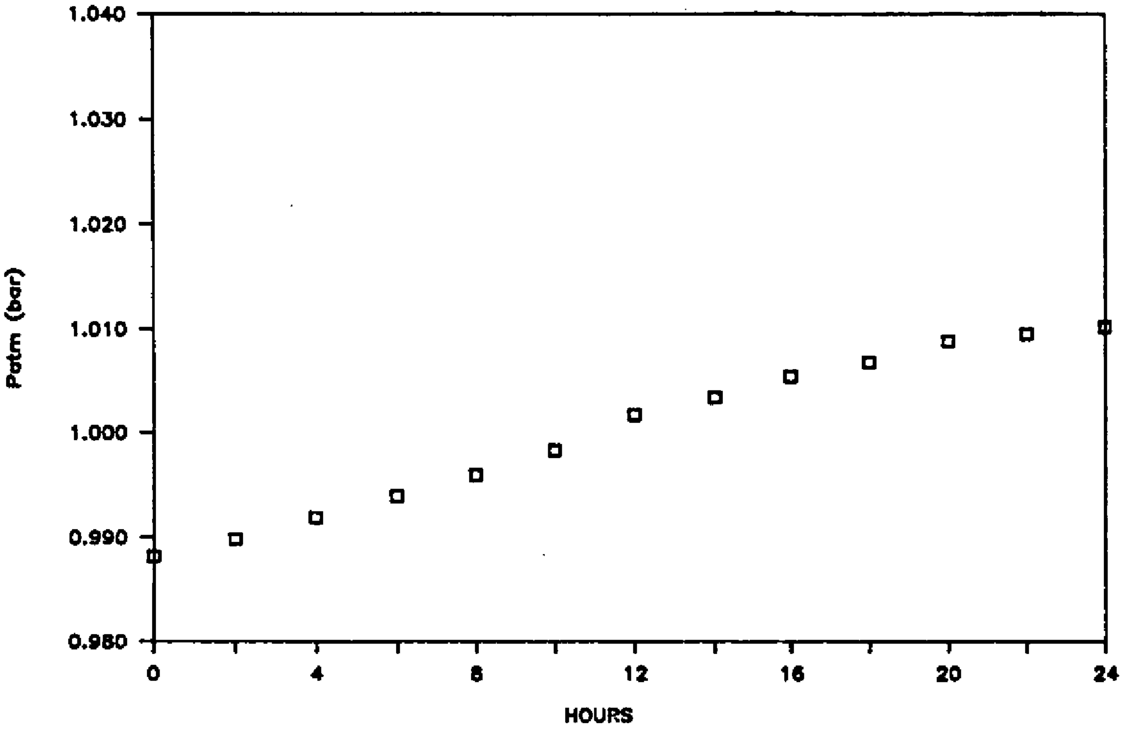
HOUR	BAROMETRIC PRESSURE Patm (bar)	CHANGE IN Patm (%)	MEASURED CALIBRATION GAS CV (MJ/sm3)	MEASURED CV ERROR (MJ/sm3)
-2	1.028			
0	1.027	-0.099	37.76	-0.01
2	1.026	-0.033	37.76	-0.01
4	1.025	-0.099	37.70	-0.07
6	1.024	-0.099	37.76	-0.01
8	1.023	-0.099	37.73	-0.04
10	1.022	-0.099	37.74	-0.03
12	1.021	-0.166	37.71	-0.06
14	1.019	-0.199	37.71	-0.06
16	1.017	-0.199	37.73	-0.04
18	1.013	-0.333	37.66	-0.11
20	1.010	-0.301	37.68	-0.09
22	1.007	-0.335	37.69	-0.08
24	1.005	-0.168	37.75	-0.02

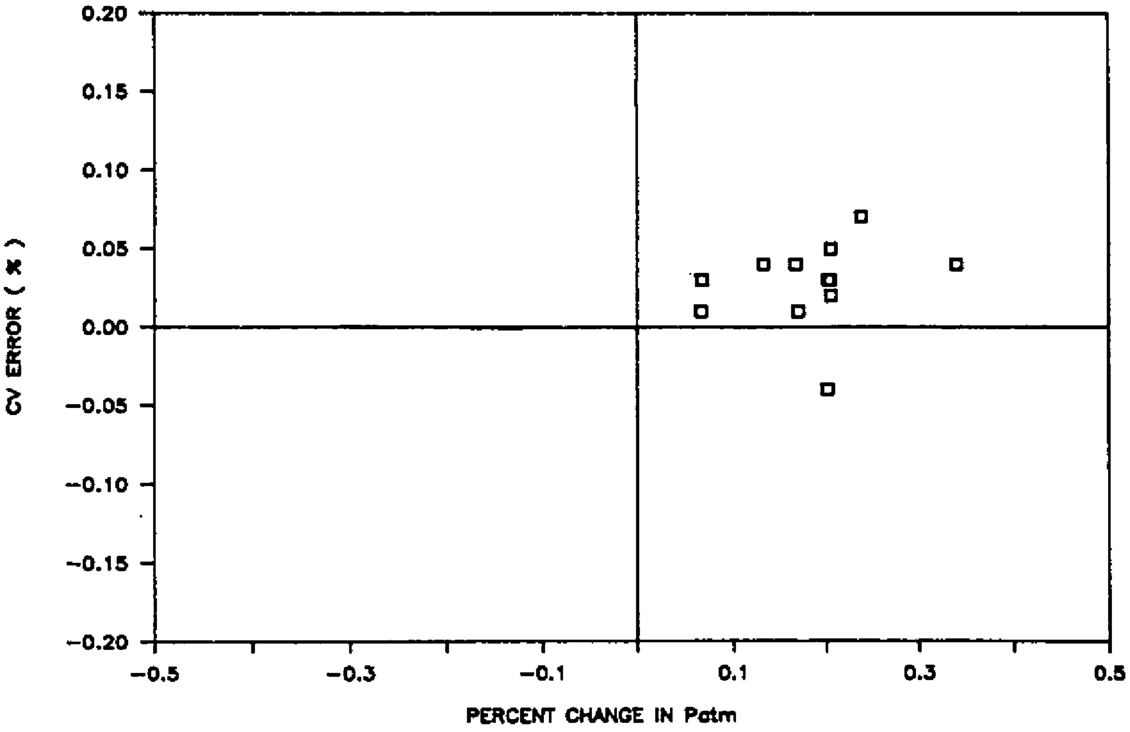




DATE: WED 31 DEC 1986 GRAPH C

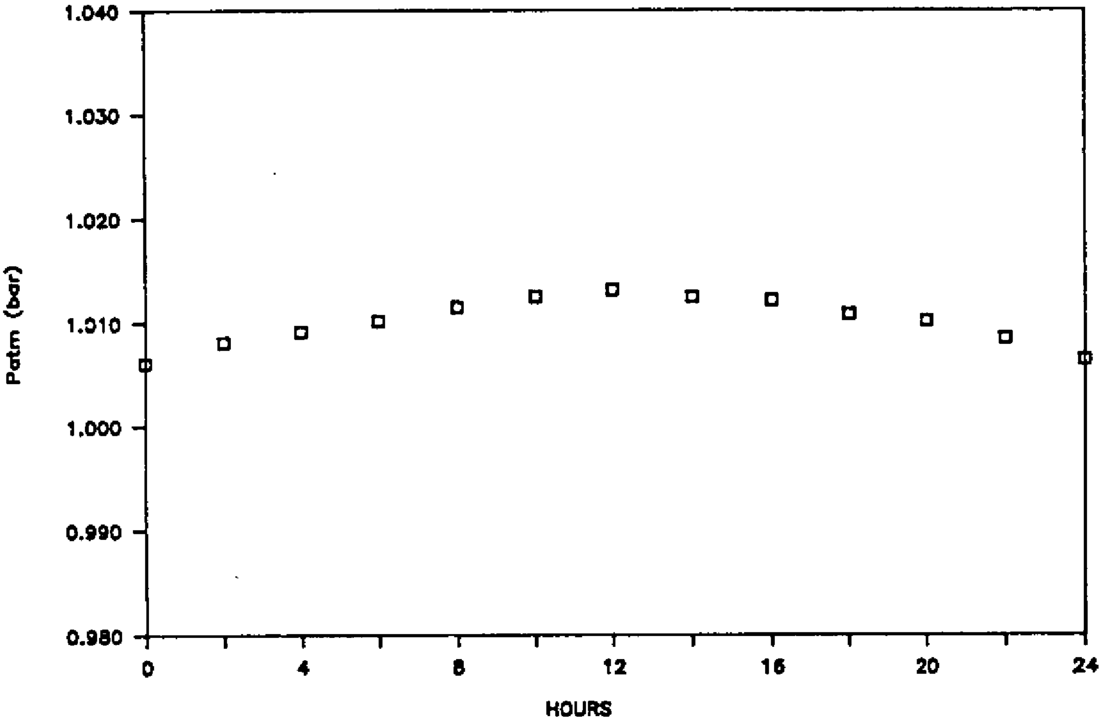
HOUR	BAROMETRIC PRESSURE Patm (bar)	CHANGE IN Patm (%)	MEASURED CALIBRATION GAS CV (MJ/sm3)	MEASURED CV ERROR (MJ/sm3)
-2	0.987			
0	0.988	0.069	37.80	0.03
2	0.990	0.171	37.78	0.01
4	0.992	0.205	37.79	0.02
6	0.994	0.205	37.82	0.05
8	0.996	0.204	37.80	0.03
10	0.998	0.238	37.84	0.07
12	1.002	0.339	37.81	0.04
14	1.003	0.169	37.81	0.04
16	1.005	0.202	37.80	0.03
18	1.007	0.135	37.81	0.04
20	1.009	0.202	37.73	−0.04
22	1.009	0.067	37.80	0.03
24	1.010	0.067	37.78	0.01

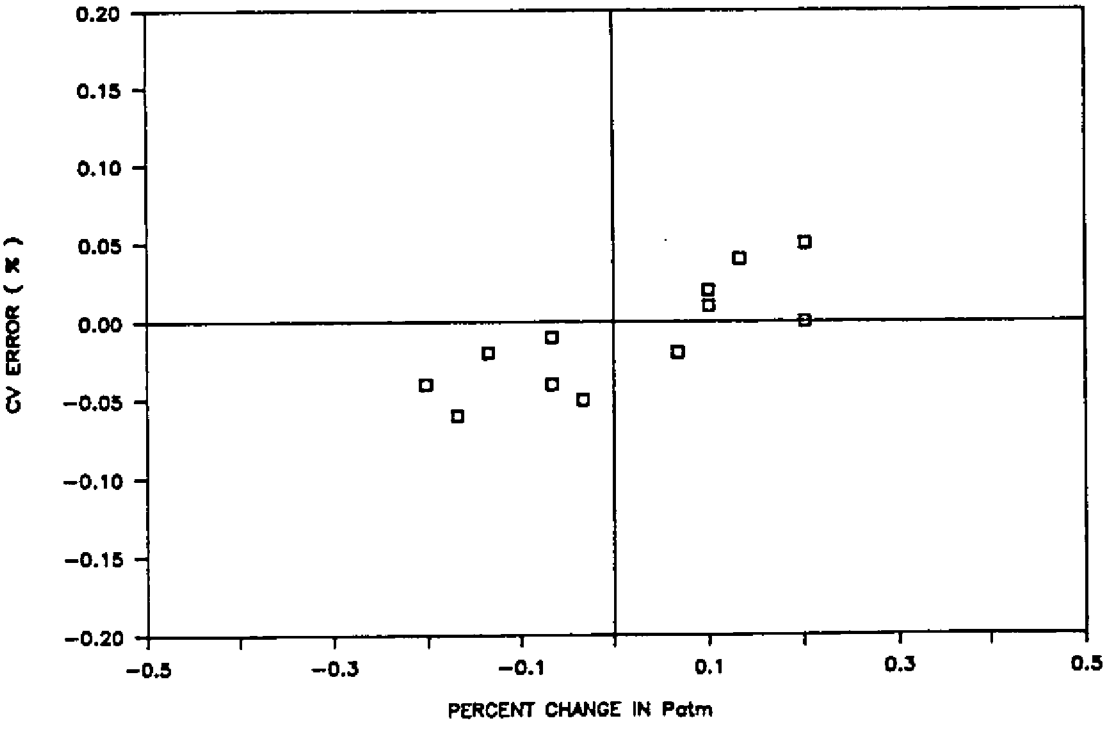




DATE: SAT 6 DEC 1986 GRAPH D

HOUR	BAROMETRIC PRESSURE Patm (bar)	CHANGE IN Patm (%)	MEASURED CALIBRATION GAS CV (MJ/sm3)	MEASURED CV ERROR (MJ/sm3)
-2	1.004			
0	1.006	0.202	37.82	0.05
2	1.008	0.202	37.77	0
4	1.009	0.101	37.79	0.02
6	1.010	0.101	37.78	0.01
8	1.012	0.134	37.81	0.04
10	1.013	0.100	37.79	0.02
12	1.013	0.067	37.75	-0.02
14	1.013	-0.067	37.76	-0.01
16	1.012	-0.033	37.72	-0.05
18	1.011	-0.134	37.75	-0.02
20	1.010	-0.067	37.73	-0.04
22	1.008	-0.168	37.71	-0.06
24	1.006	-0.201	37.73	-0.04

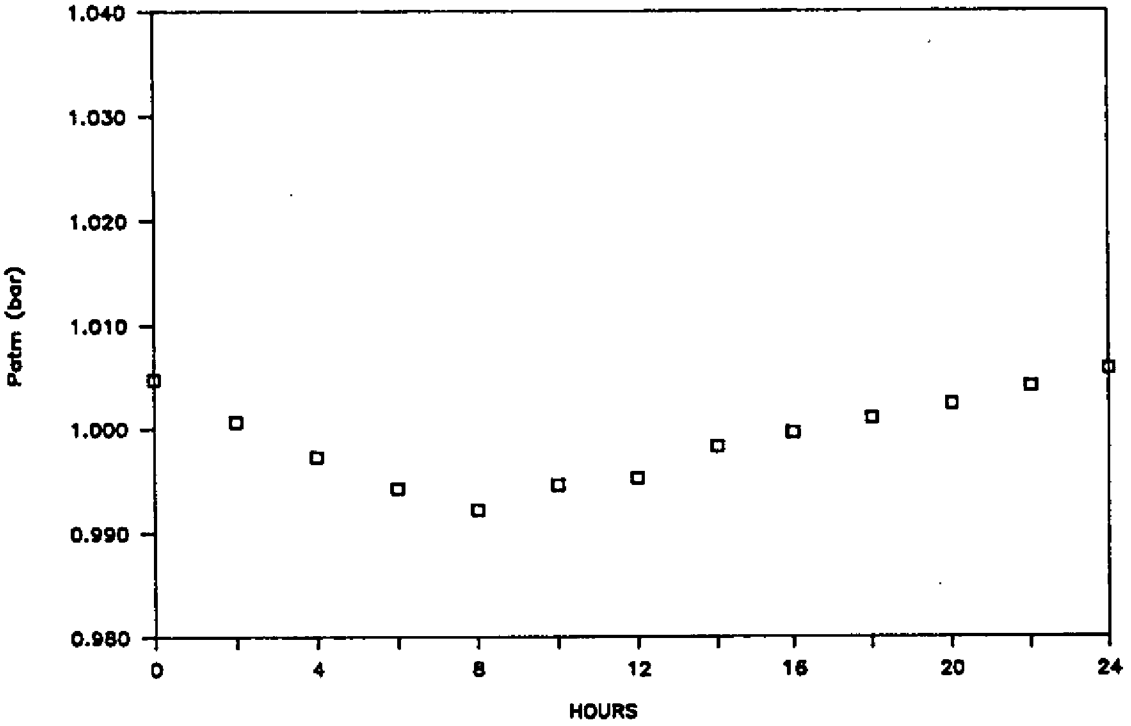


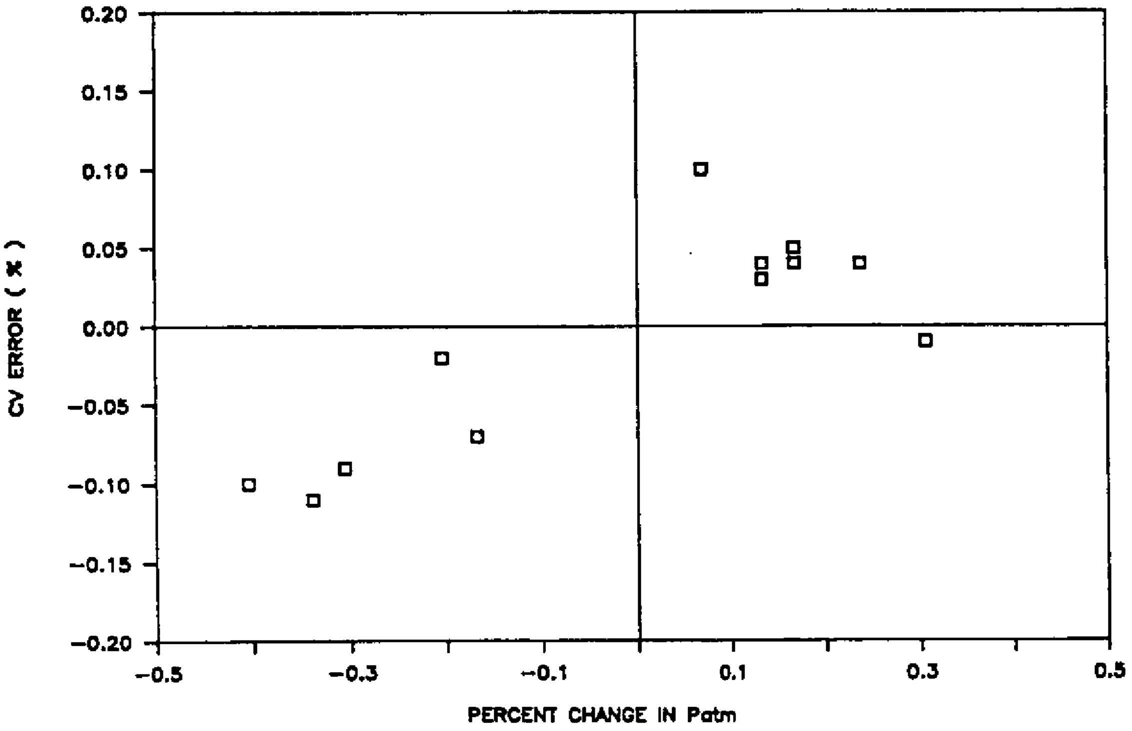


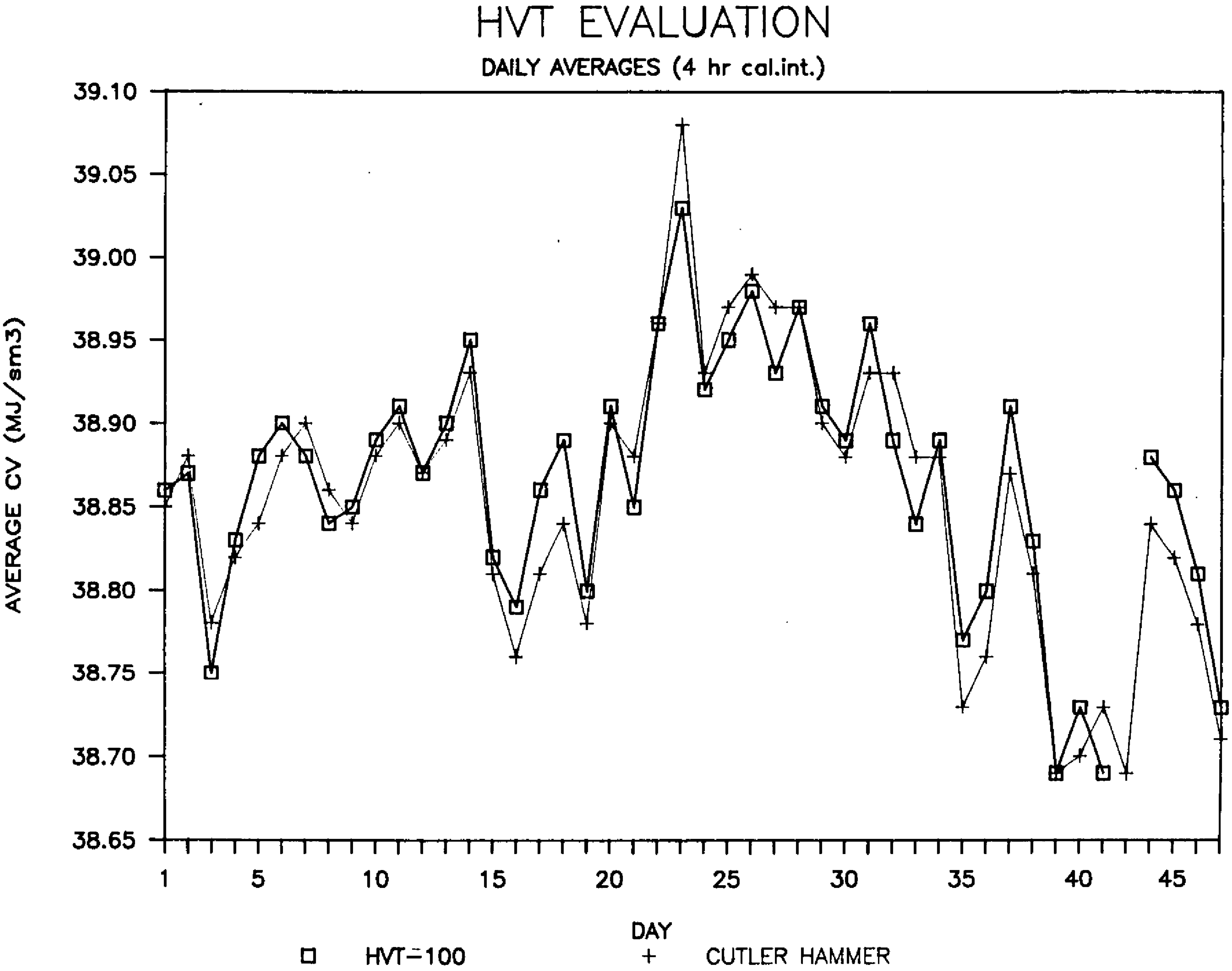
DATE: FRI 5 DEC 1986

GRAPH E

HOUR	BAROMETRIC PRESSURE Patm (bar)	CHANGE IN Patm (%)	MEASURED CALIBRATION GAS CV (MJ/sm3)	MEASURED CV ERROR (MJ/sm3)
-2	1.006			
0	1.005	-0.168	37.70	-0.07
2	1.001	-0.404	37.67	-0.10
4	0.997	-0.338	37.66	-0.11
6	0.994	-0.306	37.68	-0.09
8	0.992	-0.204	37.75	-0.02
10	0.995	0.239	37.81	0.04
12	0.995	0.068	37.87	0.10
14	0.998	0.306	37.76	-0.01
16	1.000	0.136	37.81	0.04
18	1.001	0.136	37.80	0.03
20	1.002	0.135	37.80	0.03
22	1.004	0.169	37.81	0.04
24	1.006	0.169	37.82	0.05







HVT EVALUATION

DAILY AVERAGES (4 hr cal.int.)

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.