RENOVATION OF EXPORT METERING SYSTEM

by

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SUMMARY

The 6 largest exportstations of Gasunie are 20 years old and need renovation. At the present, they are equipped with orifice plates. For the choice of the new flow metering concept additional information was needed. This was provided by 2 research projects: VEREX and KAREX. The projects gave a solid base for the new concept consisting of 2 flow meters put in series: a turbine meter as primary device and a 4-path ultrasonic meter as backup device.

In the projects both laboratory and field tests were carried out with 300 mm (12") and 500 mm (20") flow meters. Existing exportstations were compared with (reference) turbine meters and meterruns with orifice plates were calibrated at the laboratory. Some results were astonishing: pipe wall roughness can create shifts in flow metering of 1,8%, while conditions remain within ISO limits.

To require flow at standard conditions volume conversion is needed. Therefore, the whole metering system is described.

1. INTRODUCTION

Based on long term contracts the N.V. Nederlandse Gasunie exports natural gas to Germany, Belgium, France and Italy. In 1989 it comprised a volume of 32 billion m_n^3, which is approximately 40 % of the total Dutch production. The export of gas started in the late sixties and the volumes are expected to remain more or less constant for the next ten years.

The gas is sold over 13 stations of which the 6 largest are equipped with orifice plate meterruns. They transport about 90 % of the export volume.

Export customers are charged for delivered energy. The calorific value of the gas is measured by means of a Cutler Hammer calorimeter. This value differs per station (Wobbe-index): 3 stations (enriched) G-gas (44,8 ± 2,1 MJ/m_n^3), 3 stations H-gas (52,8 ± 3,0 MJ/m_n^3).

Characteristics of the 6 stations are given in table 1.

Station	pipe size [mm]	no. of meter-runs	max. station capacity [10^6 m_n^3/h]	gas quality	export to
Oude Statenzijl	300	3	0,556	H-gas	Germany
's Gravenvoeren	400	4	1,225	H-gas	Belgium/France
Bocholtz	500	4	1,42	H-gas	Italy
Winterswijk	500	4	1,44	G-gas	Germany
Hilvarenbeek	500	5	2,25	G-gas	Belgium/France
Zevenaar	500	6	2,91	G-gas	Germany

Table 1. Characteristics of exportstations after renovation.

The exportstations were built according the state of the art between 1968 and 1973. At that time the only international proven and accepted measuring instruments for large gasflows were orifice plates. Turbine meters were still in their infancy and no experience with large size meters was available. In addition, calibration stations for large turbine meters were not yet available and standards did not require calibration of orifice plate meterruns.

Now, after 20 years of continuous service, renewal of the instrumentation is needed. Maintenance is becoming more difficult and spare parts will be either no longer available in the foreseeable future or very expensive. So a redesign of the whole instrumentation is intended.

This paper will describe the present and the new metering system and summarize the major arguments and the results of the experimental tests on which the new metering system is based. It will focus on the flow measurement, volume conversion and the related experiments.
Only were an interaction of flow calculations with gas chromatograph data is inevitable, it will be subject of discussion. The research related to the calorific value is mentioned without further arguments. It will be reported elsewhere.

2. PRESENT METERING SYSTEM.

The general lay out of the export stations is given in figure 1.

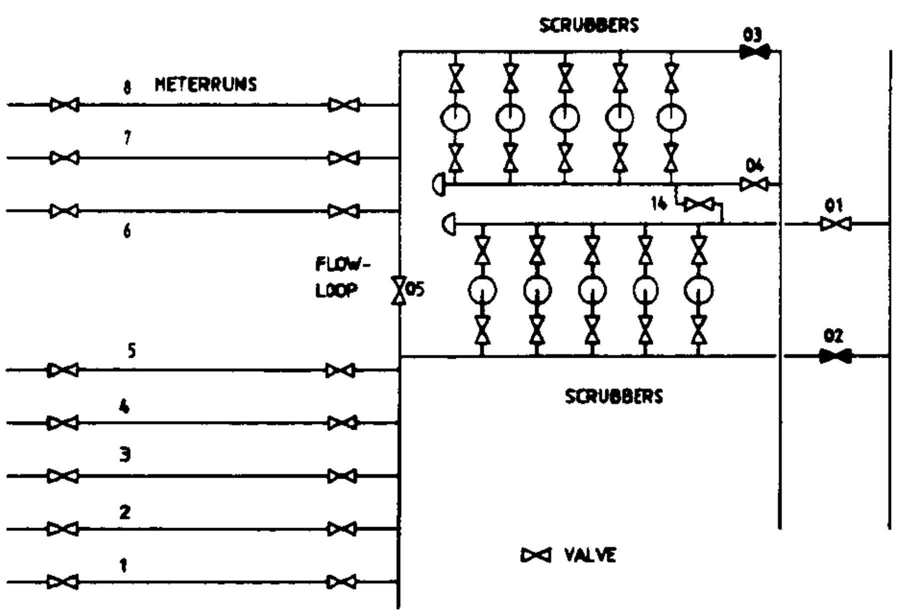

Figure 1. General lay out Gasunie export station.

The operating pressure is about 52 bar (contract minimum: 49 bar), except for the Oude Statenzijl station, where the contract minimum is 64,7 bar.
The layout of the orifice plate meterrun is given in figure 2.

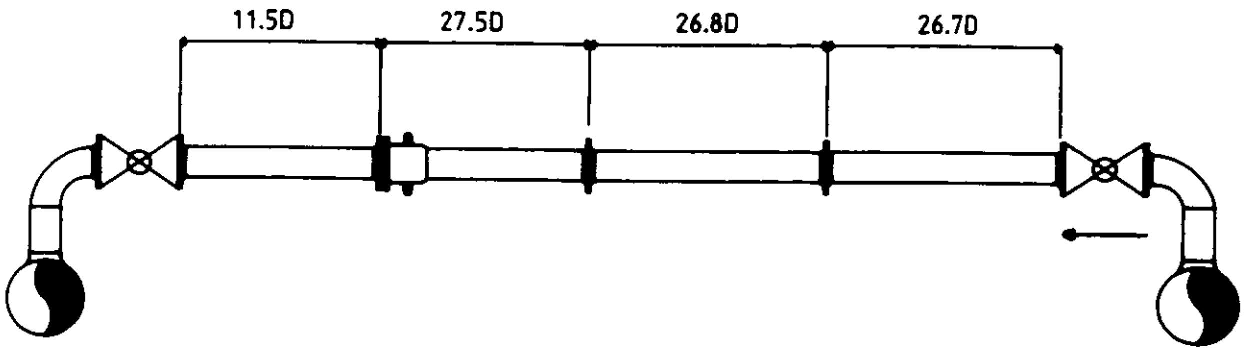

Figure 2. Present orifice plate meterrun.

All piping (up- and downstream lengths) and calculations are in accordance with the ISO 5167 standard(1). Before gas enters the meterrun, it leaves the header through a tee and passes a straight length of about 2,5 D and a 90° bend. This construction forms a "double elbow out of plane" and is known as swirl producer. But measurements 31 D downstream of this "double elbow out of plane" demonstrated the absence of swirl. This location of measuring is 27 D upstream of the position of the orifice plate.
The orifice plates are typically of beta 0,6 - 0,7 and meet the ISO standard.
The differential pressure is measured with balances of Desgrange et Huot.
Conversion to standard conditions is done on basis of density and specific gravity measurements. A flow chart of the present metering system is given in figure 3.

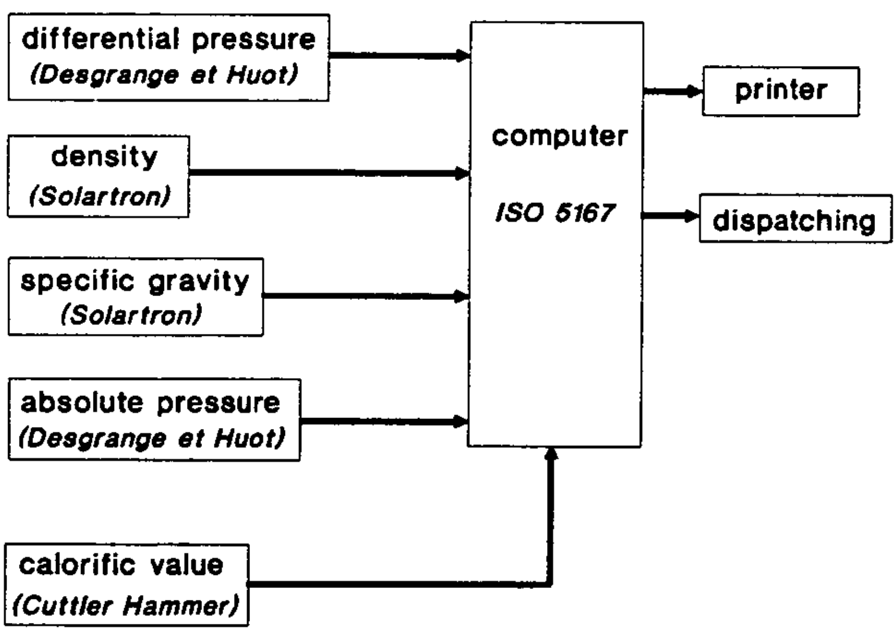

Figure 3. Present metering system.

All instruments involved in the flow calculation are one way or another backuped and checked against independent references if possible.
The differential pressure measurement is checked in a continuous sequence with a separate balance. Once a year this balance is calibrated against a dead-weight-tester.
On each meterrun density is measured with two density cells. The specific gravity is also measured twice, for the whole station.

The pressure is measured with an absolute pressure balance (also Desgrange et Huot). The measured value is not only used in the flowcalculations, but also by central dispatching to control the network and guard contractual obligations. In case of power failure the station has battery powered differential pressure and temperature recorders as backup (not included in figure 3).

In the present situation a number of critical parts can be pointed out:

- The computer is outdated, no spare parts and service can be guaranteed by the manufacturer.
- The differential pressure balances are worn out and need at least overhauling (costs per balance: $ 50,000 overhauling; $ 100,000 new)
- The density interface in some cases causes problem due to heat production.
- The Cutler Hammer has an availability of approximately 95% and the required (expensive) airconditioning installation needs overhauling.

3. GENERAL REQUIREMENTS FOR RENOVATION

According to export contracts and the policy of Gasunie, the measurements of the delivered energy shall be according to the state-of-the-art techniques, on an economical basis.
In the autumn of 1988 Gasunie formulated the requirements for the renovation of the instrumentation at exportstations:

- no blockage of gasflow, not during renovation nor during normal operation.
- reliable instrumentation with highest possible availability.
- the highest accuracy possible, since small systematic error have large financial consequences.(e.g. 0,1% ≡ $ 3,2 mil. a year)
- proven and internationally accepted technology.
- double measurement, with a complete backup metering system
- backup devices will be based on different measuring principles and will be accurate enough to check the primary devices continuously and in cases of failure take over from the primary devices.
- unmanned operation, with telemetry to the central dispatching.
- minimal pressure drop over and minimal meterruns in metering stations.

With these requirements the choice for type of instrumentation had to be made. A decision had to be formulated using the existing data in literature but also Gasunie own experiences.
The replacement of the orifice plate by a turbine meter as primary flow metering device was fairly obvious, but for some other choices extra research was needed. Especially in the choice for the backup flow meter: either a vortex meter or a 4-path ultrasonic meter, a solid basis had to be provided.
In chapter 6 an overview is given of the major arguments on which the decisions are based.

4. VEREX RESEARCH PROJECT.

4.1 Objectives

The VEREX project was initiated in 1988 and had the following objectives:
A. investigate the performance of an exportstation with orifice plates under field conditions.
B. investigate the long term performance of different flow instruments.

4.2 Introduction

The flow meters to be tested in this project were available in 300 mm (12") size. Considering this restriction only the "Oude Statenzijl" export station could be used. This station transports H-gas to Ruhrgas A.G., Germany.

4.3 Method

A flowloop was designed that could be installed in series with the existing piping of the export station. As the flowloop should not interfere with the orifice meterruns, it was built as a bypass of the scrubber section upstream of the meterruns.
Because of the pattern of flowrate over the previous years 250 mm (10") reference turbine meters were chosen. In the flowloop, besides the reference turbine meters 4 other and different types of flow meters were installed:
- a 300 mm 4-path Daniel ultrasonic flowmeter,
- a 300 mm Rockwell Auto Adjust turbine meter,
- a 300 mm direct energy flowmeter, make P.M.I.,
- a insertion type ultrasonic flowmeter, make Stork Servex.

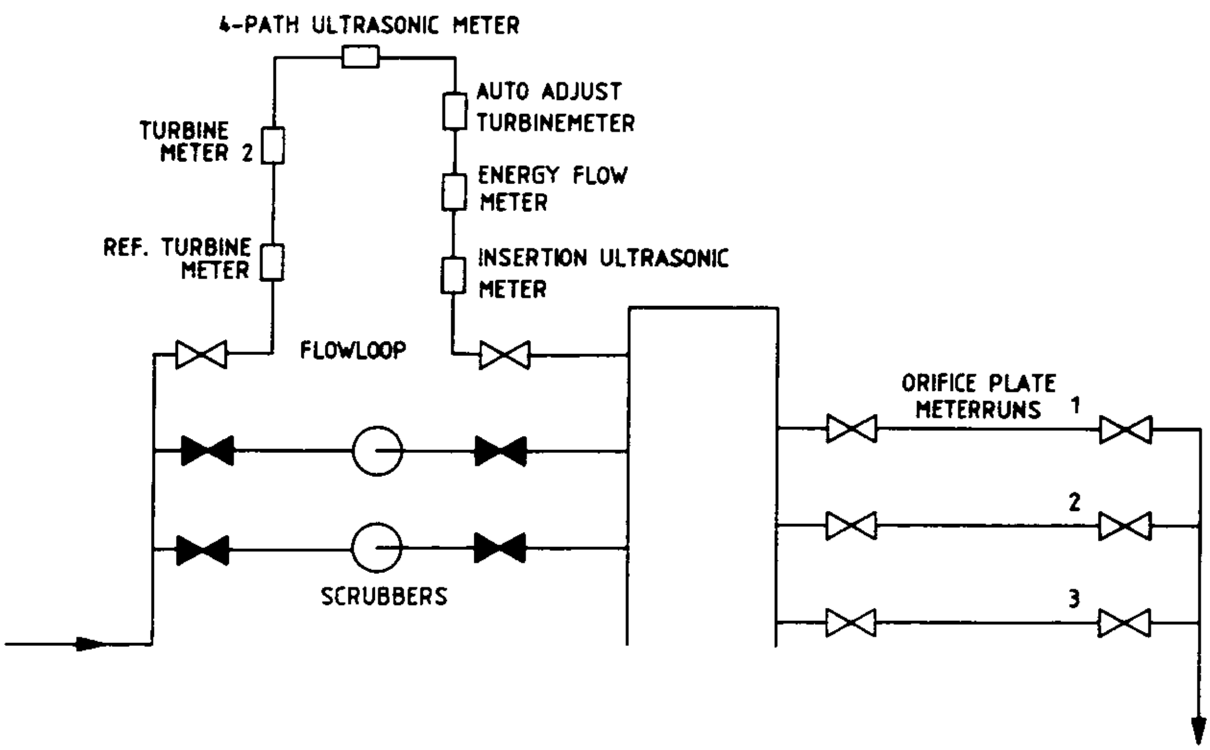

Figure 4. Initial flowloop at Oude Statenzijl exportstation

The flowloop has been in use in its original form from early July 1989 to early October 1989.
In October, an increase in flow made it necessary to re-design the loop and change to a 300 mm reference turbinemeter instead of the two 250 mm turbine meters. This also gave the opportunity to install a vortex meter on the position of the energy flow meter. The vortex meter was kindly made available by Ruhrgas A.G. Measurements with the re-designed loop were made from November 1989 until January 1990. During this period the flowrate was higher and less constant than in the previous period. Because of this and of the fact, that the flowloop was connected to previous dead-ends of the manifold, accumulated sand and pebbles came loose when the flowrate was increased.

The flowloop as a whole was calibrated at the Westerbork laboratory, prior to and after the tests at the exportstation. This includes all flow devices and secondary equipment. These calibrations were performed in presence of the authorities of NMi (Dutch Service of weights and measures).
Comparisons are made based on massflow determined with PTZ (pressure, temperature, compressibility) and the (5 components) GERG equation.

4.4 Results

The flowrate was rather different during both measuring periods. The pattern is shown in figure 5.

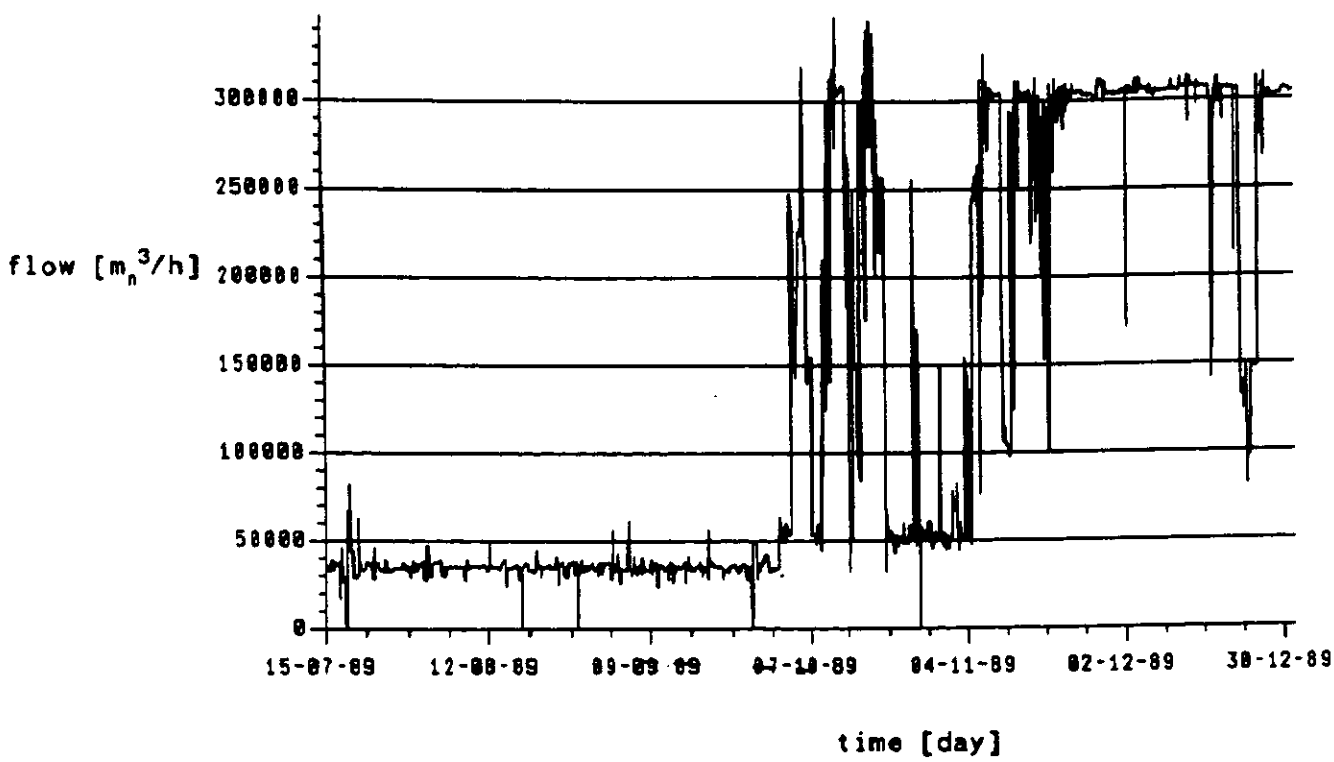

Figure 5. Flowrate from mid July until end December 1990.

During the first period the difference in flow readings between the orifice plate meterruns of the exportstation and the first 250 mm reference turbine meter is established and is based on daily averages.

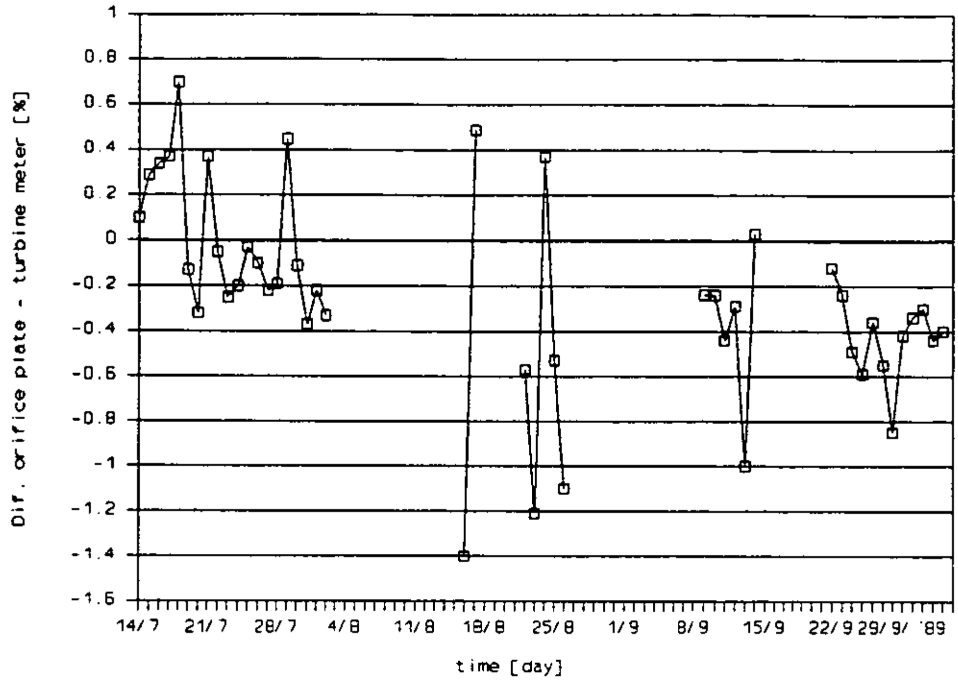

Figure 6. Difference in time between orifice plate meterruns and reference turbine meter at the Oude Statenzijl exportstation.

Intercomparisons between the other meters in the flowloop are made on mass flow and hourly basis. Some shifts were detected in the difference with the reference turbine meter. After careful data analysis and instrumentation check, it was found that some of the Pt-100 temperature transmitters had been drifting due to corrosion of the contacts. After correction for those drifts, the shifts in the differences decreased significantly. An example of correcting for drift of a temperature transmitter is given in figure 7.

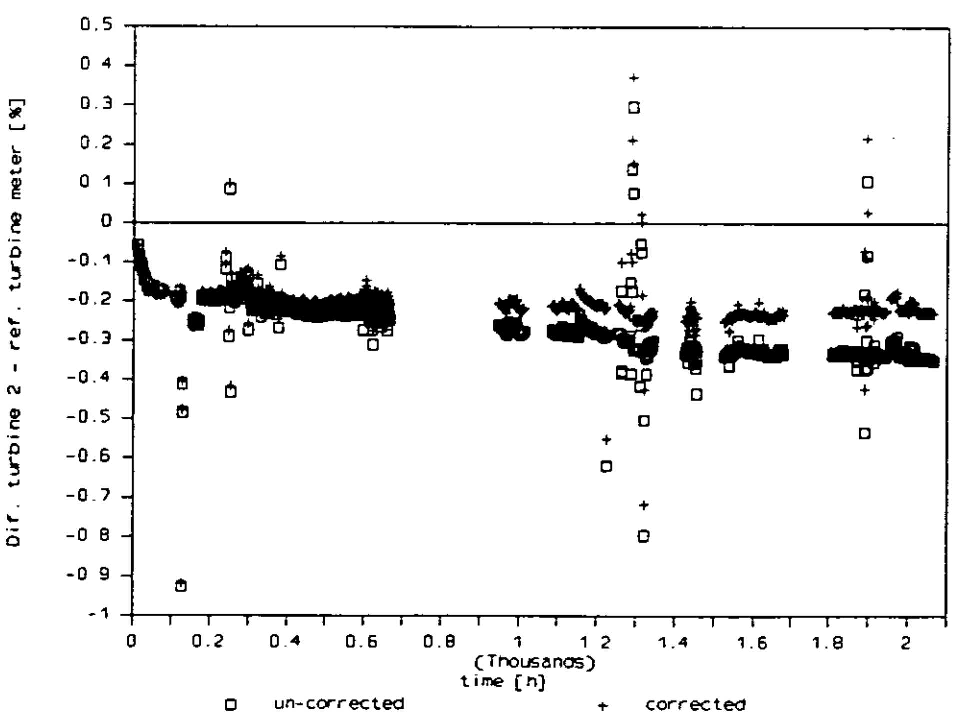

Figure 7. Difference in time between turbine meter 2 and ref. turbine meter, corrected and uncorrected for drift of temperature transmitter.

Figures 8 and 9 are based on measurements after installation of the re-designed loop. They show the differences of the ultrasonic meter and the vortex meter related to the reference turbine meter.

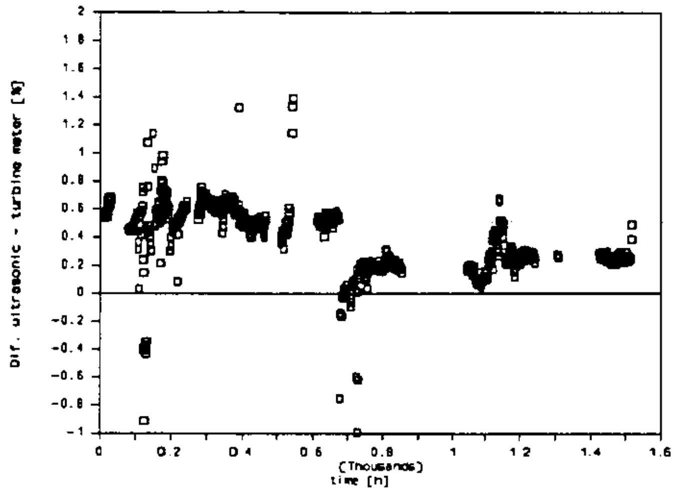

Figure 8. Difference in time between ultrasonic and reference turbine meter.

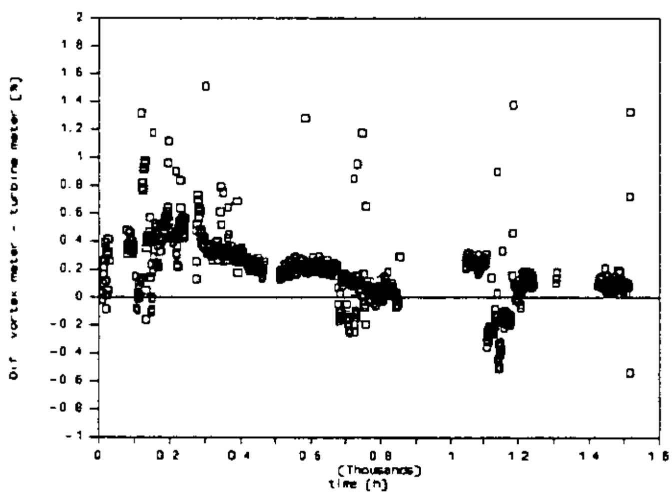

Figure 9. Difference in time between vortex and reference turbine meter.

From the figures we observe a shift in the difference after the flow has been up to 4000 m3/h. Later at the re-calibration it was confirmed that the reference turbine had shifted 0,4%. As cause for the shift of the turbinemeter it was found that the edge of the outer ring of the blade housing was damaged by sand and pebbles from the dead-end.
Although not desirable under normal operation this result shows that both potential backup meters, ultrasonic and vortex meter were able to detect the shift. It also emphasizes that both backup meters were not affected by the rough conditions.

4.5 Conclusions

The conclusions from the experiments at Oude Statenzijl are:

- The orifice plate installation reads 0,25 % low.
- The orifice plate installation is sensitive for dynamic flow behavior.
- The turbine meter cannot stand coarse dirt.
- The ultrasonic meter and the vortex meter perform well under rough conditions
- The vortex meter has larger spread in measurement values than ultrasonic meter (field conditions, hourly basis: ± 0,3%, resp. ± 0,2%)

5. KAREX RESEARCH PROJECT.

5.1. Objectives

The KAREX project started in June 1989 and has the following objects:

A. detect and quantify possible shift in flowmetering due to the renovation of the exportstations.

B. provide a solid basis for the choice of the new flowmetering concept.

5.2 Introduction

Major gasflow is measured with 500 mm meterruns (see table 1) and therefore even small shifts in flow measurement will have a significant impact on the companies gasbalance. Therefore, the tests in this project are focussed on the 500 mm (20") size.
In the new metering concept, a turbinemeter and a backup meter are placed in series, which is rather new for this size of meters. Further more, there was no experience with the backup meters that were considered: vortex meter and 4-path ultrasonic meter in the 500 mm size. To reduce pressure drop the vortex meter is in 500 mm size and is <u>not</u> equipped with a flow straightener.

To provide a solid basis for the new metering concept, tests were not only conducted at a laboratory (Westerbork), but also in the field at an exportstation. The Hilvarenbeek station has a configuration offering the possibility to perform a field test in 500 mm size. It has 8 meterruns, but due to decreased gas sales only 5 meterruns are in use as a maximum. In short distance is the Belgian metering station called Poppel. This station checks the measurements of the Hilvarenbeek station and is also equipped with 500 mm orifice plate meterruns. Distrigaz made their data available during the tests.

The objectives of 5.1 resulted in the tests described in the following 4 sections:

Test A1:
Because of the over capacity, 2 entire meterruns could be removed from the Hilvarenbeek station and calibrated in the Westerbork laboratory.(paragr. 5.3)

Test A2:
Instead of the 2 removed meterruns a flowloop with a 600 mm (reference) turbinemeter was placed in series with the export station. (paragr. 5.4)

Test B1:
New flow metering concepts with a turbinemeter and either a vortex meter or a 4-path ultrasonic meter were tested in an adapted meterrun from test A1. (paragr. 5.5)

Test B2:
In Hilvarenbeek a meterrun with an orifice plate was rebuild according the new metering concept. (paragr. 5.6)

In all tests, volume conversion of the flow meters is based on the PTZ (pressure, temperature, compressibility) method using the 5-component GERG equation. Gas quality is measured with gas-chromatographs. Volume conversion of the Hilvarenbeek metering station is based on direct measurements.
(cf. chapter 2) The volume conversion of the Poppel metering station is also based on direct measurement, but with a correction using a Z-meter [2].
The meters used in the field tests are error curve corrected.

5.3 Test A1. Measurements on an orifice plate meterrun at the laboratory (Westerbork).

5.3.1 Method

Two entire 500 mm orifice plate meterruns (each 44 meters long) were transported from Hilvarenbeek to Westerbork and both were calibrated against the reference meters of Westerbork. The meterruns are of different make: Daniel and Robinson and have different tapping hole diameters: 9,5 mm and 13 mm. To a large extend hardware, software and experience from the EC 600 mm orifice plate project could be used.
When the meterruns were dismantled in Hilvarenbeek it was noticed that there was a thin (< 0,5 mm) deposit on the inner walls of the pipes. After transportation to Westerbork it took some weeks before the pipes could be installed. In those weeks the deposit came partly loose and the inner walls of the pipes slightly corroded. As the results of the flow measurements did not correspond with the findings at Hilvarenbeek (cf. section 5.4) it was decided to give special attention to roughness effects:

1. pipe wall roughness.
2. roughness of upstream side of orifice plate.

To investigate the influence of pipe wall roughness, the pipesection (27 D) upstream of the Daniel orifice plate carrier was cleaned and coated. During cleaning and coating care was taken that the edge sharpness of the tapping holes was not changed. Flow profile in pipes with different roughness was also measured.
To detect influence on flow reading the roughness of the upstream side of both the Robinson and Daniel ß = 0,64 (12") orifice plates were changed.

5.3.2 Results.

For the Robinson meterrun several orifice plates were available, ranging from: ß = 0,37 to 0,74 (hole diameter: 7" to 14").

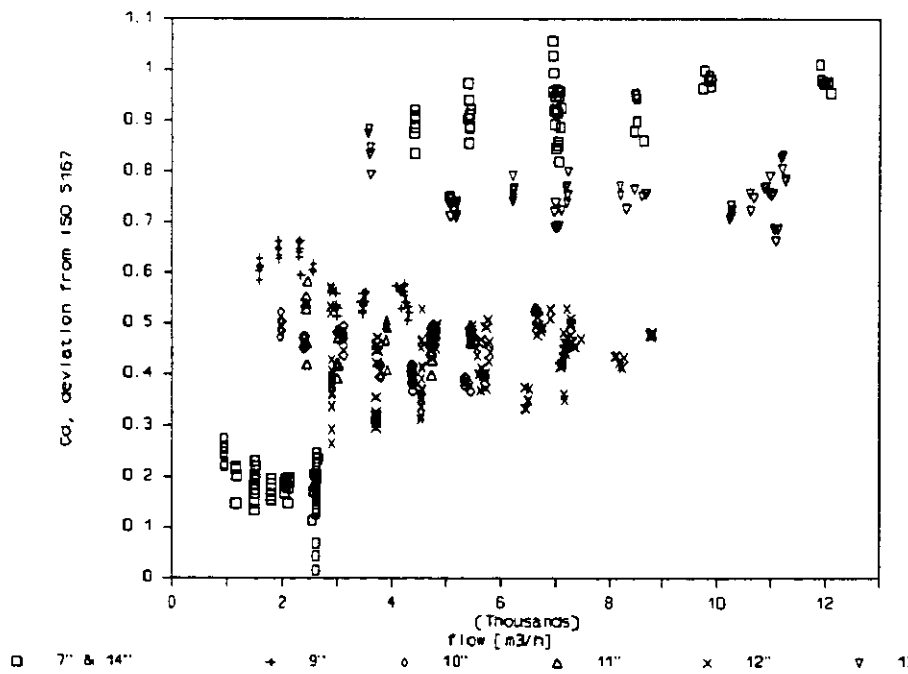

Figure 10. Deviation of discharge coefficient Cd from ISO 5167 as a function of flow rate for several orifice plates with different beta's.

For the Daniel meterrun 2 orifice plates were available with ß = 0,64 and 0,69 (hole diameter: 12" and 13"). These sizes are commonly used by Gasunie. The flatness of the ß = 0,64 (12") orifice plate was bad: a maximal difference of 1.48 mm was found (still within ISO limits!). This is probably the cause for the strongly increasing deviations at the lower flows. Figure 11 shows the deviation from ISO for both orifice plates and both roughnesses of the inner pipe wall.

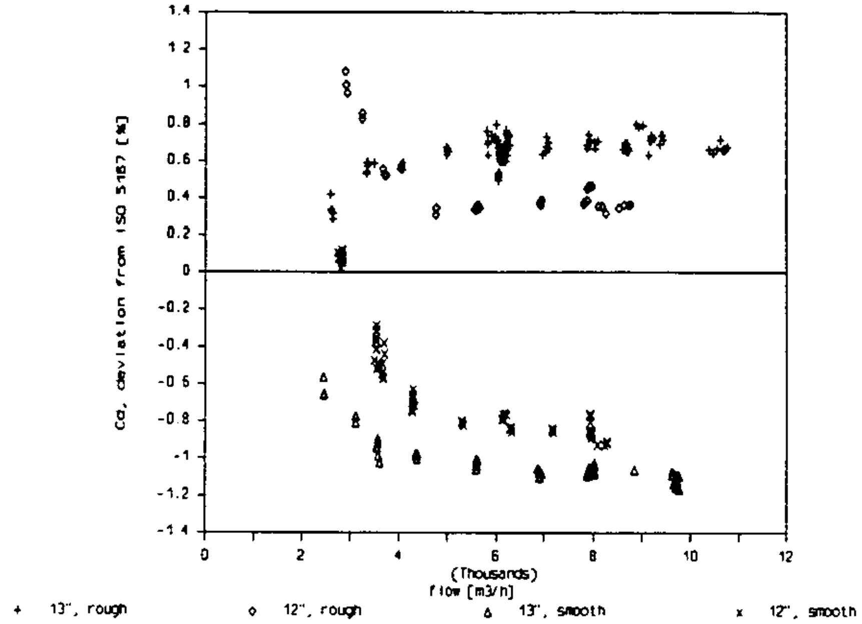

Figure 11. Shift in Cd due to roughness of pipe wall as a function of flow rate for 2 different orifice plates.

In Westerbork flow profile behind a rough and a cleaned and coated (smooth) pipesection was determined. In Hilvarenbeek this was done behind a pipesection with the thin deposit. Results are shown in figure 12.

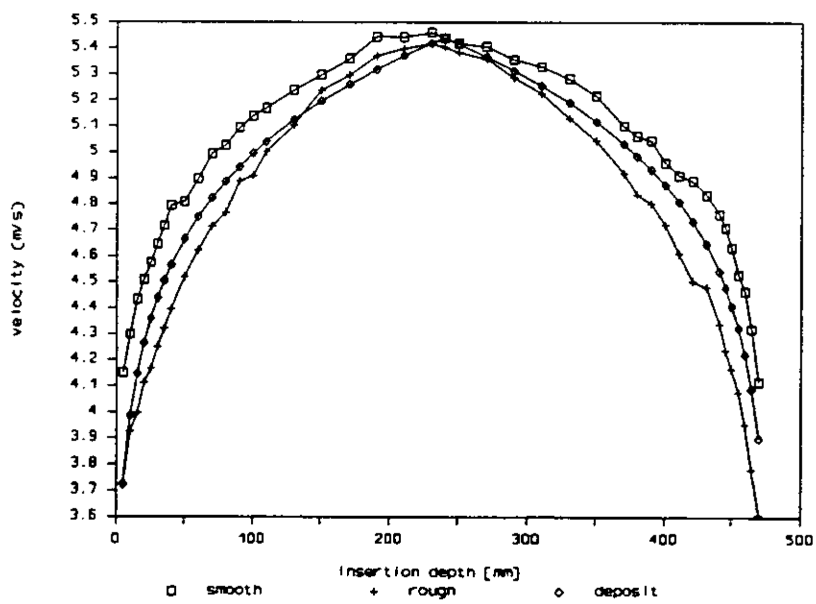

Figure 12. Flow profiles for pipes with different roughness

In table 2 results of roughness measurements, exponents of power law approximation of flow profile and deviations in Cd value from ISO with different pipe wall roughness are given. Measurements of the pipe wall roughness also showed that the values of the Robinson and the Daniel meterrun were corresponding.

pipe wall surface	roughness	power law exponent	Cd deviations from ISO 5167 (ß = 0,69)
rough	Rz = 140 µm	8.2	+ 0.7
deposit	Rz = 70 µm	10.5	+ 0.1
cleaned and coated	Rz = 30 µm	12.5	- 1.1
Limit pipe wall roughness according ISO 5167: k = 478 µm Rz (ten point height) and k (uniform equivalent) are corresponding roughness figures			

Table 2. Roughness values, power law exponents and Cd deviations from ISO for pipes with different roughness.

The results of changing the roughness of the upstream side of ß = 0,64 (12") orifice plates are given in table 3. When changing the roughness, care was taken not to influence the edge sharpness. During the measurements with the 10 µm orifice plate flow fluctuations were somewhat larger than during the other measurements. To a certain extend the flow fluctuations are the cause for the change in Cd value.

make meterrun	roughness upstream pipe	change in roughness of orifice plate from, to	change in discharge coefficient
Robinson	rough	Ra = 0,24 µm to 2 µm	no change
Robinson	rough	Ra = 2 µm to 10 µm	< 0.2 % increase
Daniel	smooth	Ra = 0,35 µm to 2 µm	< 0.1 % increase
Limit according ISO 5167: Ra = 30 µm The Ra roughness figure gives the arithmetic average over a given length			

Table 3. Change in discharge coefficient due to roughness of upstream side of orifice plate.

Combination of the results found with the results of previous projects: the 100 mm[3,4], 250 mm[5] and 600 mm[6,7] EC projects and the 600 mm NIST/GRI measurements[7] is shown in figure 13.

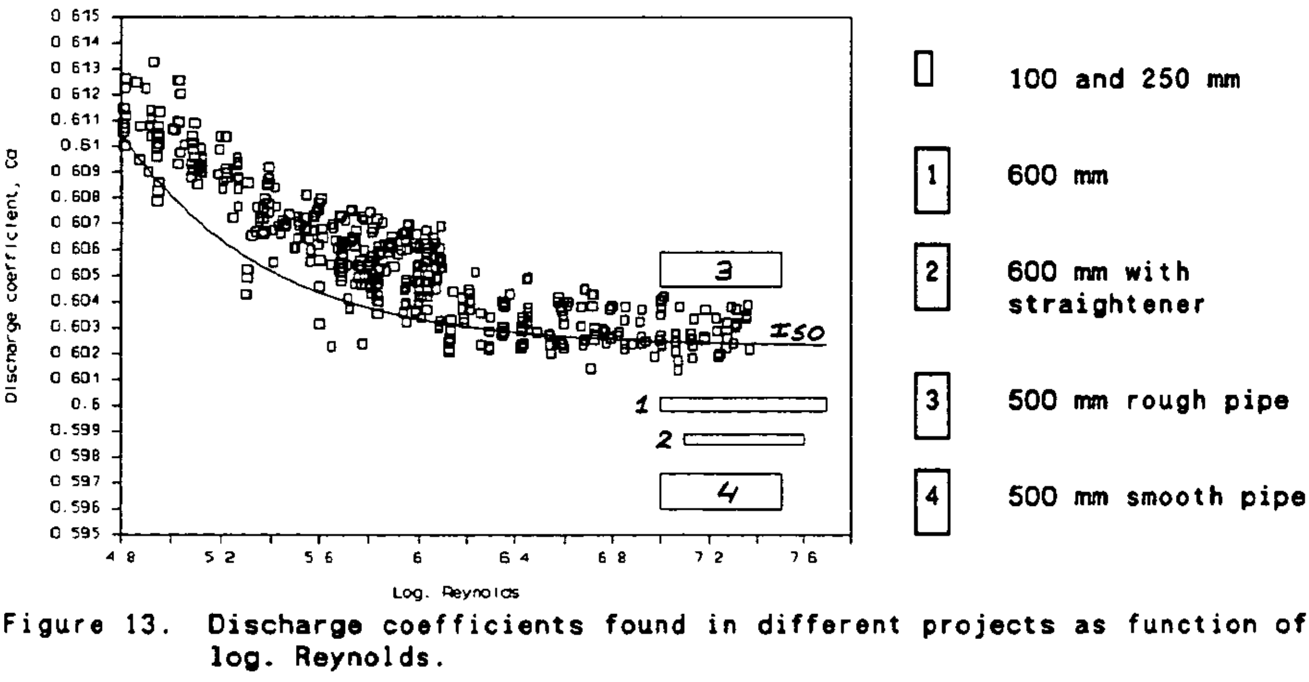

Figure 13. Discharge coefficients found in different projects as function of log. Reynolds.

5.3.3 Conclusions.

The results indicate, that:

- The deviations from ISO are large (up to 1,1 %)
- The deviations from ISO <u>increase</u> with <u>increasing ß</u>.
- The wall roughness of the upstream pipesection has large influence on flow measurement
  a change in pipe-wall-roughness from Rz = 140 µm to 30 µm results
  with ß = 0,64 in an <u>increase</u> in flow reading of about <u>1.3%</u>
  with ß = 0,69 in an <u>increase</u> in flow reading of about <u>1.8%</u>
- The wall roughness has large influence on flow profile
- The roughness of the upstream side of the orifice plate has <u>no significant influence</u> on flow reading, when orifice plates with larger ß-values (0.64) and 500 mm size are used
- The make of meterrun has no influence on flow reading

5.4 Test A2. Comparison on flow metering of an export-station against a 600 mm (reference) turbine meter (Hilvarenbeek).

5.4.1 Method

Instead of the 2 removed meterruns a flow loop with a 600 mm turbine meter is build. In the header is a ball valve (no. 05) by which the 600 mm flowloop can be brought in either metering or in by-pass condition. Because of maximum capacity of the 600 mm turbine meter no measurements can be taken in the winter period. Figure 14 shows the Hilvarenbeek station with the flowloop installed and in metering condition.

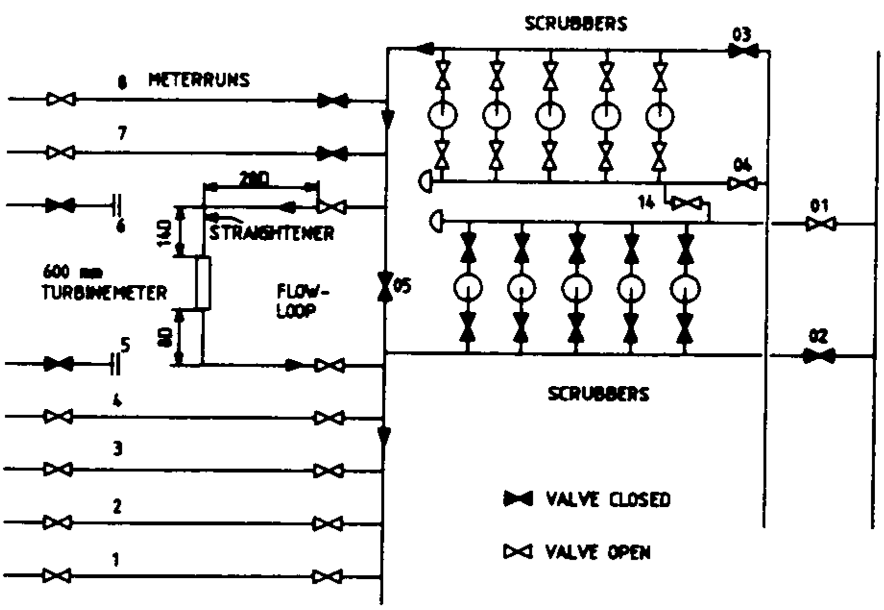

Figure 14. Lay out of the Hilvarenbeek exportstation with flowloop with 600 mm (reference) turbine meter.

The performance of meterruns 1 until 4 is compared against the 600 mm (reference) turbinemeter. This is done prior to and will be done after the renovation.
The turbinemeter was calibrated in Westerbork by NMi in November 1988 and re-calibrated in November 1989, after the first measurements in Hilvarenbeek. The meter will again be re-calibrated after the test series B2 (winter 1990-1991)

and after the comparative measurements with the all renovated meterruns (autumn 1991). In the EC 600 mm orifice plate project, British Gas did measurements on this meter and found results which corresponded within ± 0.15 % with the NMi calibration. It must be emphasized that the traceability lines of Bishop Auckland (British Gas) and Westerbork (NMi) are totally independent.
In 5.3 was found that the influence on pipe-wall-roughness is very large. Therefore, a large part of the Westerbork tests (different orifice plates and coated upstream piping) were repeated in Hilvarenbeek. Results of these additional tests are not available at the moment of writing.

5.4.2 Results.

The 1988 and 1989 calibration of the 600 mm turbinemeter are shown in figure 15.

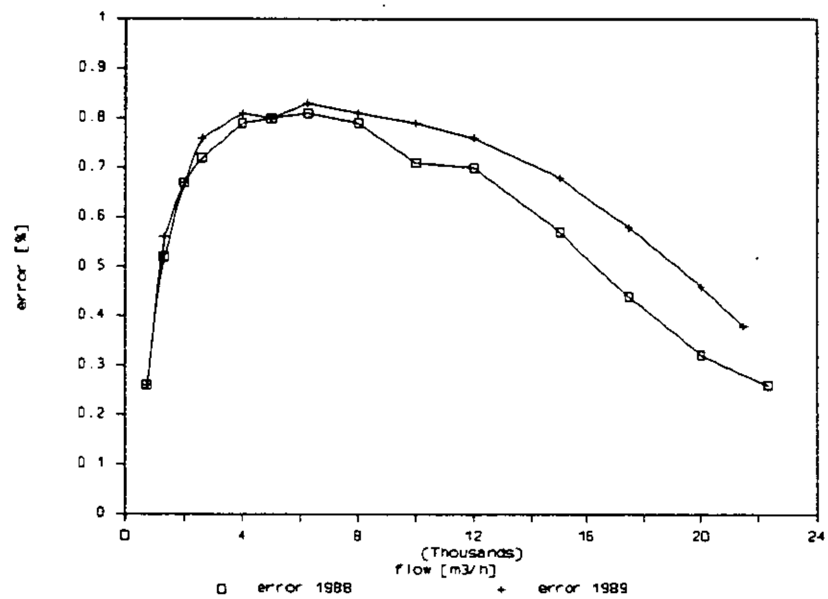

Figure 15. Calibration curves of 600 mm (reference) turbine meter.

Figure 16 shows the difference in hourly readings between the 600 mm turbinemeter and meterruns 1 to 4 of the Hilvarenbeek metering station.

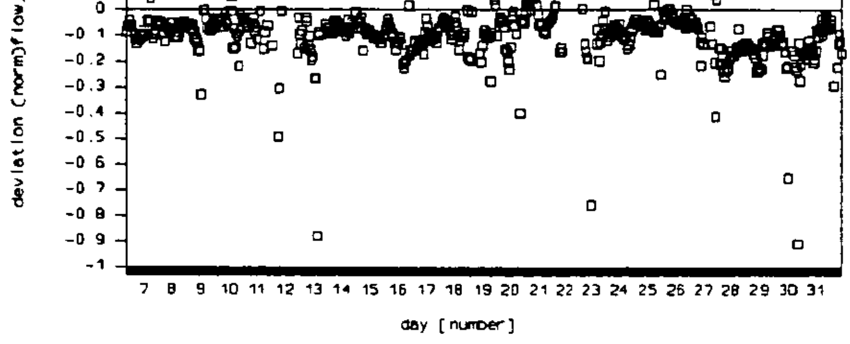

Figure 16. Difference in time between the 600 mm turbine meter and orifice plate meterruns 1 - 4 of the Hilvarenbeek exportstation.

The averaged difference is 0.1%, but flow fluctuations, for instance due to switching of meterruns, cause very large differences (up to 5%). The differences between the meterruns is within 0,3%. The averaged difference between the Poppel station and the 600 mm turbinemeter is a little bit larger: 0,3%. The flowrate during the measurements ranges between 200.000 and 1.000.000 m_n^3/h.

5.4.3 Conclusions.

The results indicate, that

- The orifice plate meterruns (1-4) of Hilvarenbeek read 0,1 % too low
- The difference in flow reading between meterruns (1-4) is small
- The orifice plate meterruns of Poppel read 0,3% too low
- The orifice plate meterruns are sensitive to flow changes
- The results of different calibrations of the 600 mm turbine meter correspond very well

5.5 Test B1. New metering concepts tested at the laboratory (Westerbork).

5.5.1 Method.

For the tests with the new flow metering concepts an 500 mm orifice plate meterrun at Westerbork was modified in correspondence with the future situation at the exportstations. The backup meters were therefore always tested in series with a turbinemeter.
For the ultrasonic meter the position is easy: upstream of the turbinemeter. For the vortex meter the position is less obvious. Therefore, the vortex meter is tested both upstream and downstream of the turbinemeter. Influence of pipe wall roughness is investigated for all meters.

5.5.2 Results.

The vortexmeter was tested in a number of meterrun configurations and results are shown in figure 17.

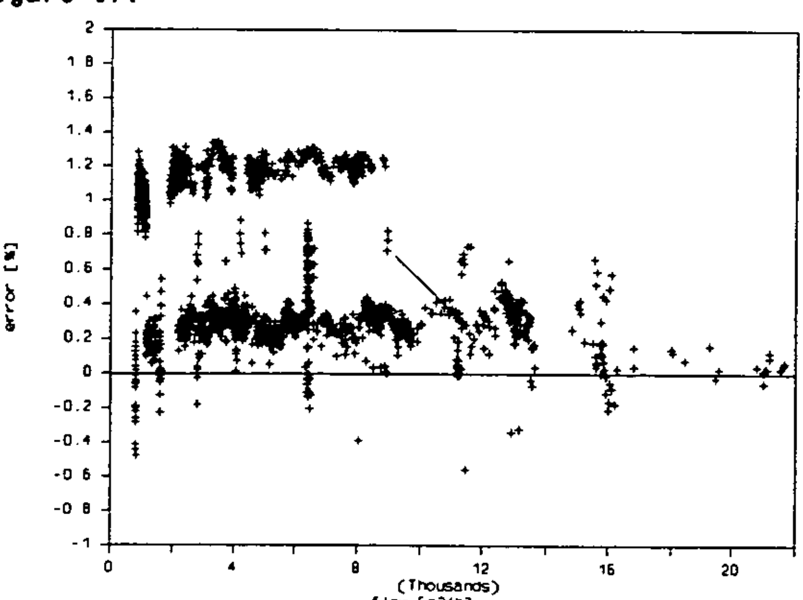

Figure 17. Error of vortex meter as function of flow for different meterrun configurations.

A configuration of vortex meter and turbine meter was tested continuously for a time period of 10 days. As the proportion pulses / flow is very low (11.2 impulse/m^3) for the 500 mm vortexmeter 15 minutes samples were taken. Figure 18 shows the results.

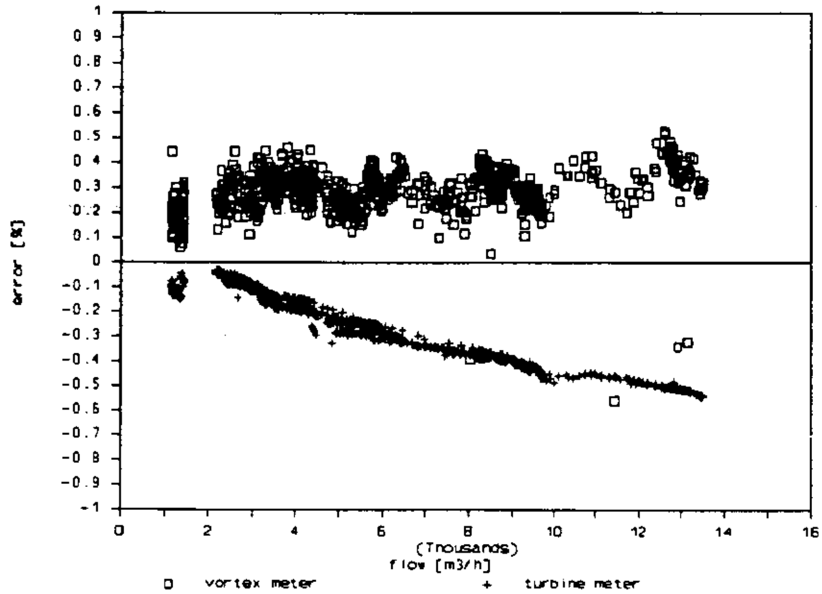

Figure 18. Errors of vortex and turbine meter as function of flow during a time period of 10 days.

The configuration of ultrasonic meter and turbine meter was calibrated and after this it ran continuously for 14 hours. The results of 5 minute samples is shown in figure 19. Of the ultrasonic meter, the analog output reading is used.

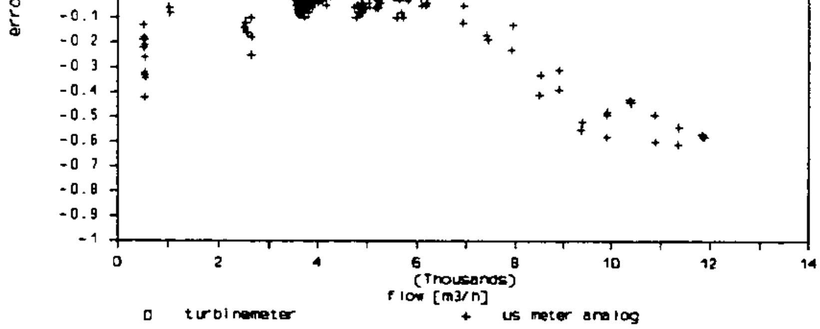

Figure 19. Errors of ultrasonic and turbine meter as function of flow.

Later on minor alterations in the hardware of the ultrasonic meter were made. The results of the calibration of the meterrun with the improved ultrasonic meter and the turbinemeter in series is given in the figure 20. Of the ultrasonic meter both the analog and the digital output were used. After the calibration the configuration was installed in Hilvarenbeek.

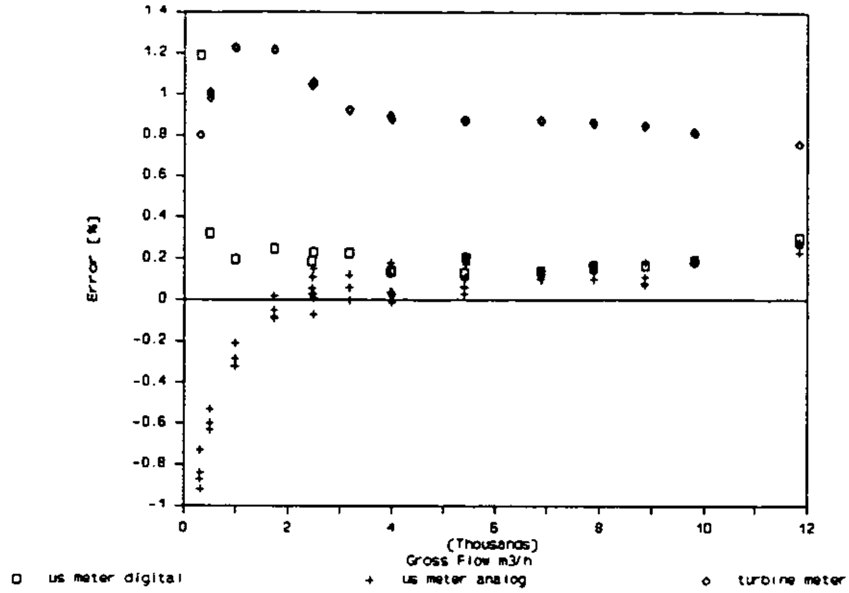

Figure 20. Errors of ultrasonic and turbine meter as function of flow at calibration.

5.5.3 Conclusions.

The results indicate, that

- The vortexmeter is sensitive for configuration effects.
- The spread in reading from the vortexmeter (± 0,2%) is larger than from the ultrasonic meter (± 0,15%)
- The repeatability of the turbine meter is excellent
- The influence of pipe wall roughness on turbine and ultrasonic meter is negligible

5.6 Test B2. New metering concept tested at an exportstation (Hilvarenbeek).

After the choice of the backup meter was made, meterrun 1 in Hilvarenbeek was rebuild. The orifice plate was removed and the new metering concept, with turbinemeter and ultrasonic meter installed. An endurance test with the concept is momentarily in progress and will last from July until December 1990. Preliminary results show an excellent accordance between the readings of the 600 mm and the 500 mm turbinemeter: within 0,1 %.
The differences between the 500 mm turbinemeter and the ultrasonic meter are within ± 0,15%.

6. CHOICE OF NEW FLOWMETERING CONCEPT

6.1 Primary flow meter.

The choice for this meter is between retaining the orifice plate or change to turbine meters. Based on literature and long term own experience the choice in favor of the turbine meter was clear and did not need the research projects described in this paper. Yet an overview of the major arguments will be given.

Figure 21 shows that even with the volume conversion included, the turbine meter is more accurate than the orifice plate.

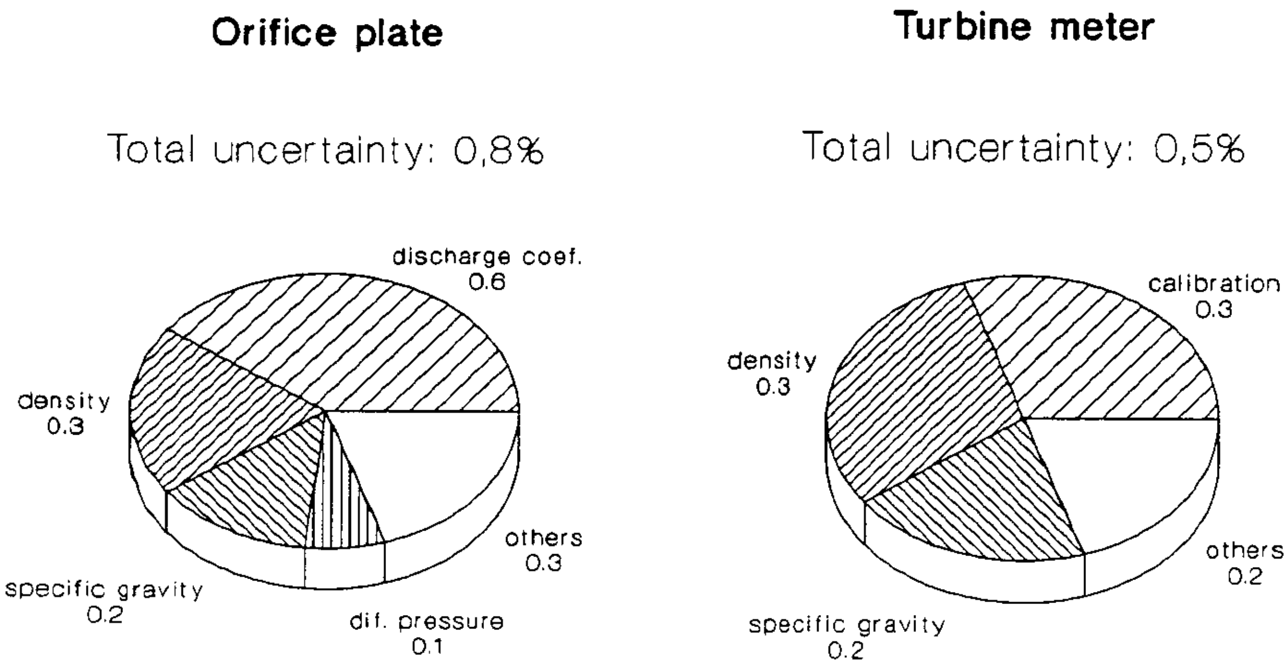

Figure 21.Uncertainty of orifice plate and turbine meter.

A major part of the uncertainty is formed by the discharge coefficient, which, according to ISO 5167 has a value of 0.6. But in literature [3 .. 12] it is shown that large metering errors (caused by e.g. swirl, pipe and plate roughness, centering of the plate, edge sharpness) can occur even in conditions which meet the ISO prescriptions. The results found in the VEREX and KAREX projects not only endorse the findings in the referred literature, but indicate a sensitiveness for interference, which is even <u>much larger</u> than was expected.
On the other hand, the turbinemeters (if not used in gas with coarse dirt) showed an excellent repeatability. This same result was found in a report[13] on 60 turbine meters, which were part of a high pressure re-calibration program.

The rangeability under high pressure gas of a turbine meter is normally larger than 1:20. Orifice plates meterruns however have a rangeability of 1:3, if the plate is not changed. With modern differential pressure transducers and switch-over a rangeability of 1:10 can be achieved, but this reduces the accuracy of the flow measurement. Because of the small rangeability of the orifice plate, metering stations require switching in parallel meterruns and this introduces large deviations in flow reading.

For a meterrun equipped with an orifice plate ISO 5167 prescribes long upstream and downstream lengths to provide a fully developed velocity profile at the orifice plate. The turbine meter requires an upstream length that is much smaller, normal 5 D.
Moreover each turbinemeter has its own mechanical backup by means of a counter on the housing.

6.2 Back-up meter

From the VEREX and KAREX projects, as well as from other tests[14,15] it was concluded that the ultrasonic flowmeter is best suited for backup flow meter at the export stations. The measurements with this meter have enough accuracy and repeatability (within ± 0.15%) to detect measurement errors of the turbine meter placed in series and if necessary take over the measurements for a limited time.

6.3 Volume conversion

Both the turbine meter and the ultrasonic flowmeter measure flow at actual line conditions. In the new concept each meter will have a flowcomputer, in which gross flow is converted to flow at standard conditions (0 °C, 101325 Pa). The flow conversion of the backup system (ultrasonic meter) is according to the PTZ method, using the GERG - 5 components equation. The method for the primary system (turbinemeter) is dependent on the preferences of the customer: either direct measurement or PTZ.

The decision to use turbine meters instead of orifice plates makes volume conversion more important. This has 2 reasons:

- with a turbine meter, the conversion is linear related with density with orifice plates however, the conversion is related with density according square root
- measurements with turbine meters are more accurate. Therefore the accuracy of density and specific gravity becomes more important; their uncertainty forms 50% of the total uncertainty of the converted volume.

6.4 Layout

The existing piping is in good condition and will therefore be re-used. With the choice for turbine meter and ultrasonic meter the lay out of the renovated meterrun is as shown in figure 22.

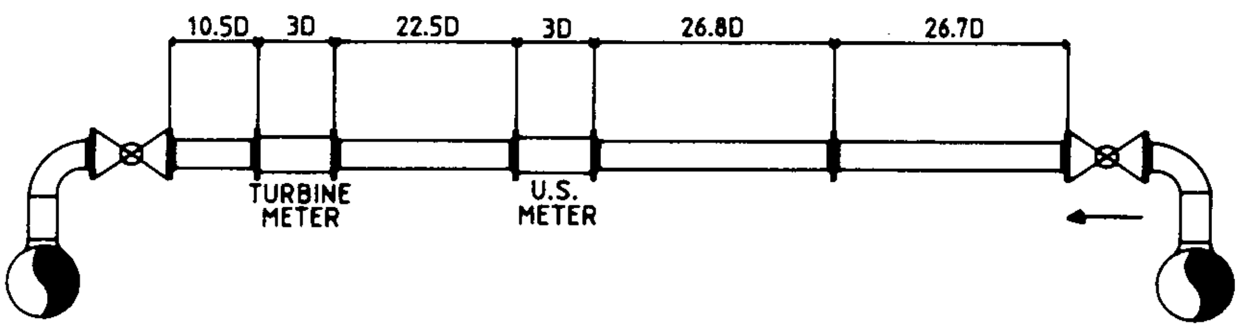

Figure 22. Lay out of new meterrun

7. NEW METERING SYSTEM

7.1 Basic design

The basic design of the new metering system is given in figure 23. It shows the lay out for 1 meterrun and with preference for density, which is directly measured.

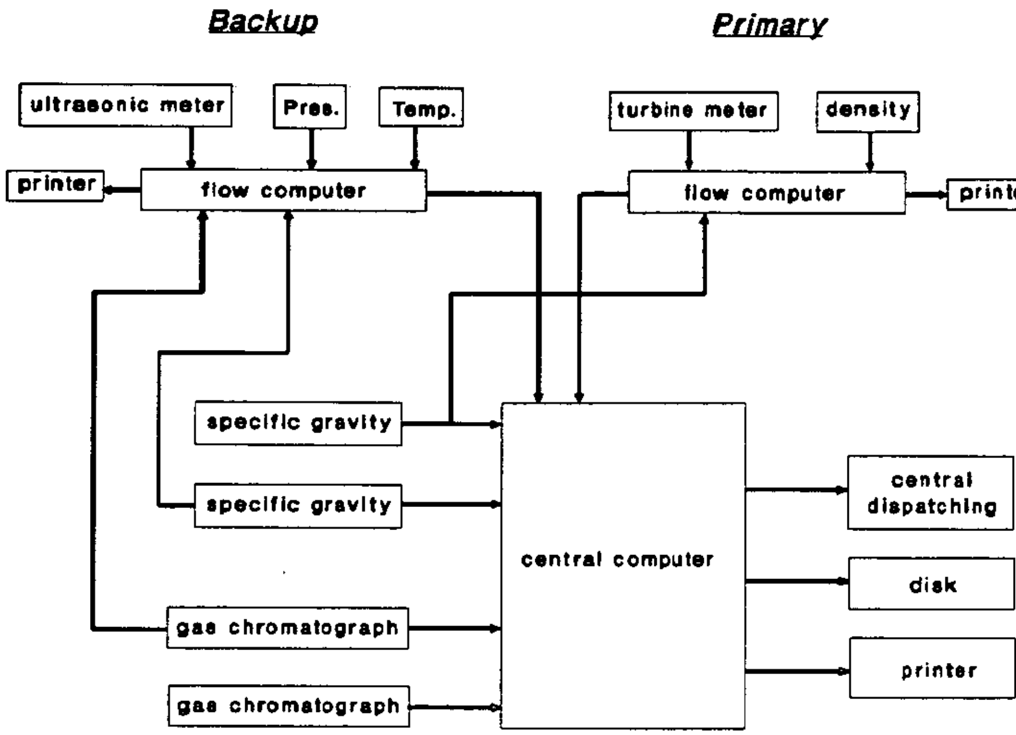

Figure 23. New metering system, for 1 meterrun and preference for measured density.

The station measurements will be supervised by a central computer, which has the following tasks:
- informing central dispatching of the actual situation (by telemetry link)
- accounting of energy flow through the station
- controlling and comparing primary and backup metering devices and systems

On the basis of comparison the central computer controls which values will be used in the accounting and when alarms have to be given. Data and status will be monitored on printers and harddisk.

Gas quality is determined per station by use of 2 identical, but independent operating gas chromatographs. They update the measured values each 15 minutes. Because of the small band of the allowable gas quality fluctuations at the exportstation the updating frequency is quit sufficient.

Each exportstation will be equipped with 2 centrally placed specific gravity density meters.

Each meterrun is equipped with a primary and a backup flow metering system. Such a system consists of a flowmeter, a flowcomputer and devices to determine the volume conversion. The flowcomputers have their own printer to monitor data and status and a transmission link to the central computer. The ultrasonic meter has digital communication with the flow computer.
In the central computer the readings of the primary and backup flow metering systems are compared per meterrun. This is done on standard volume and at least

once an hour.

7.2 Preferences on volume conversion

The method used for volume conversion of the primary flow meter (turbine meter) is dependent on the preferences of the customer:

A. preference for use of direct measurements (density meters). (Germany / Italy) The flow computer uses readings of: turbine meter, density meter and specific gravity density meter.
B. preference for use of PTZ method. (Belgium / France) The flow computer uses readings of: turbine meter and by digital communication from the gas chromatograph: CO_2, specific gravity and calorific value.

The backup flow metering system will use the PTZ method and readings of: pressure, temperature, specific gravity density meter, calorific value from the gas chromatograph (analog signal) and a fixed CO_2 value.
At the moment of writing final details are discussed with the supplier of the central and flow computers.

8. CONCLUSIONS

In this paper we present the research on flow measurement that was involved in the renovation of the Gasunie exportstations. It provided the solid base for the change over from orifice plate to a new flow metering concept, consisting of a turbine meter as primary device and a 4-path ultrasonic meter as backup device.

Changing from orifice to turbine emphasis the need for proper volume conversion, where especially the compressibility calculation is important.
Incorporating the conclusions a total new metering system is presented which shall be put in operation mid 1991.

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