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# IMPROVED CHOKE VALVE DESIGN FOR DE-BOTTLENECKING GAS PROCESSING FACILITIES


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## ABSTRACT


Twister BV core competence lies in modelling gas behaviour, leading to the development of the Twister™ Supersonic Separator. This supersonic gas conditioning technology allows the condensation and separation of water and natural gas liquids from natural gas, without the use of chemicals and associated regeneration systems. The simplicity and reliability of this static device, with no rotating parts, operating without chemicals, ensures a simple, environmentally friendly facility, with a high availability, suitable for de-manned operation.

Twister BV has now developed and tested a new type of choke valve by making use of Twister BV proprietary CFD models. The Twister **SWIRL™** valve enhances the coalescence of dispersed liquids in a fluid stream, thereby improving the efficiency of downstream separators. During a recent field test at a NAM JT-LTS production unit, it has been demonstrated that replacement of a conventional JT-valve with the Twister SWIRL Valve, resulted in a significant improvement in the overall dew-pointing performance of the gas processing facility. This retrofit also allowed the NAM operators to increase the plant flow rate from their initial maximum of 600,000 $Nm^3$/day to more than 735,000 $Nm^3$/day, whilst still meeting export gas specifications. It was further found that by utilising the SWIRL Valve, the temperature in the cold separator (SMSM type) could be increased by 4 - 5 °C whilst still meeting specification, allowing a reduction in the plant feed pressure of about 3 bars.

During the field test it was also discovered that the normally-experienced glycol losses were significantly reduced. The SWIRL valve tests, performed in close co-operation with NAM and Mokveld, met all of the NAM and Twister BV test criteria. This new product is now available for debottlenecking applications on existing JT-LTS modules, or for improving new-built JT-LTS units.

This paper presents an overview of Twister SWIRL Valve technology as well as the main results of the field test at the NAM gas production facility.

## SWIRL Valve Technology description

Pressure throttling in a conventional choke valve is normally achieved by dissipation of kinetic energy present in randomly distributed eddies. The SWIRL Valve uses the excess free pressure in a fluid stream to establish a coherent vortex motion. The total pressure inside the vortex core is reduced gradually along the axis of the flow path. By reducing the total pressure in a vortex flow, the flow shear rates are lower compared to conventional chokes, thereby avoiding excessive break-up of liquid drops. However, and more importantly, these micron-size droplets are concentrated around the perimeter of the flow path in a SWIRL valve, thus enhancing the coalescence to larger, more easily separable droplets.

**Figure 1** below shows the basic principle of the SWIRL valve versus a normal cage-piston type valve.

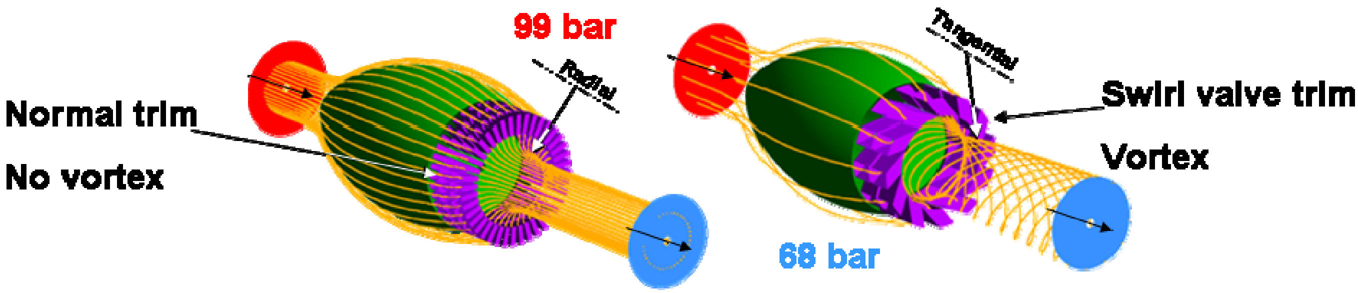


**Figure 1: Flow paths of conventional cage valve (left) and SWIRL cage valve (right)**

In order to assess the coalescence efficiency of the two different valve designs, analytical calculations and numerical analyses were performed. This data showed that the time to increase droplet sizes from 4 micron (non-separable) to 20 micron (separable) is in the order of milliseconds for the SWIRL valve, compared to several seconds for normal valve designs. The concentration of the liquid fraction along the outer perimeter of a SWIRL valve, vis-à-vis a traditional valve, is shown in **Figure 2** below. The SWIRL valve requires only 20-50 cm straight pipe length for the droplets to reach the pipe wall, whereas a conventional cage valve needs 20-50 metres.

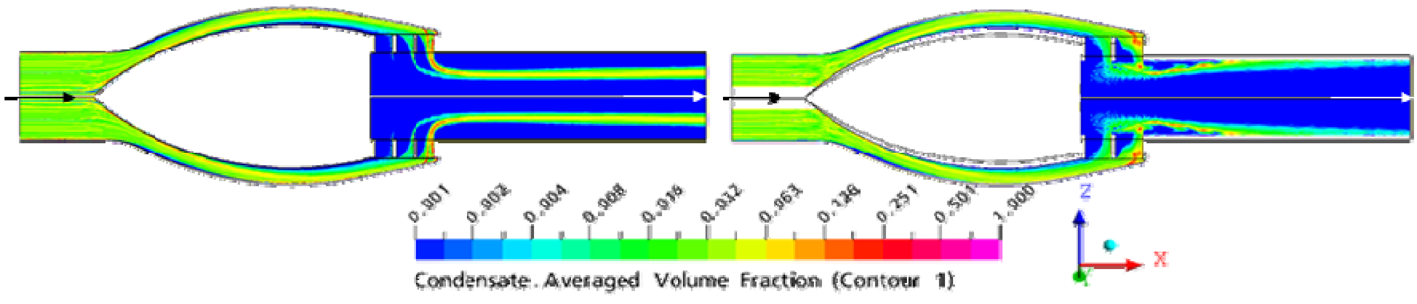


**Figure 2: Liquid volume fractions for a conventional cage valve (left) and SWIRL cage valve (right)**

The centrifugal forces exerted on the liquid droplets in the SWIRL valve design (right) result in a concentration, and hence coalescence, of droplets around the perimeter of the outlet of the valve. In a conventional cage-piston valve (left), the liquid fraction will not coalesce along the wall surface. **Figure 3** shows the effect on the overall separation performance of a SMSM separator.

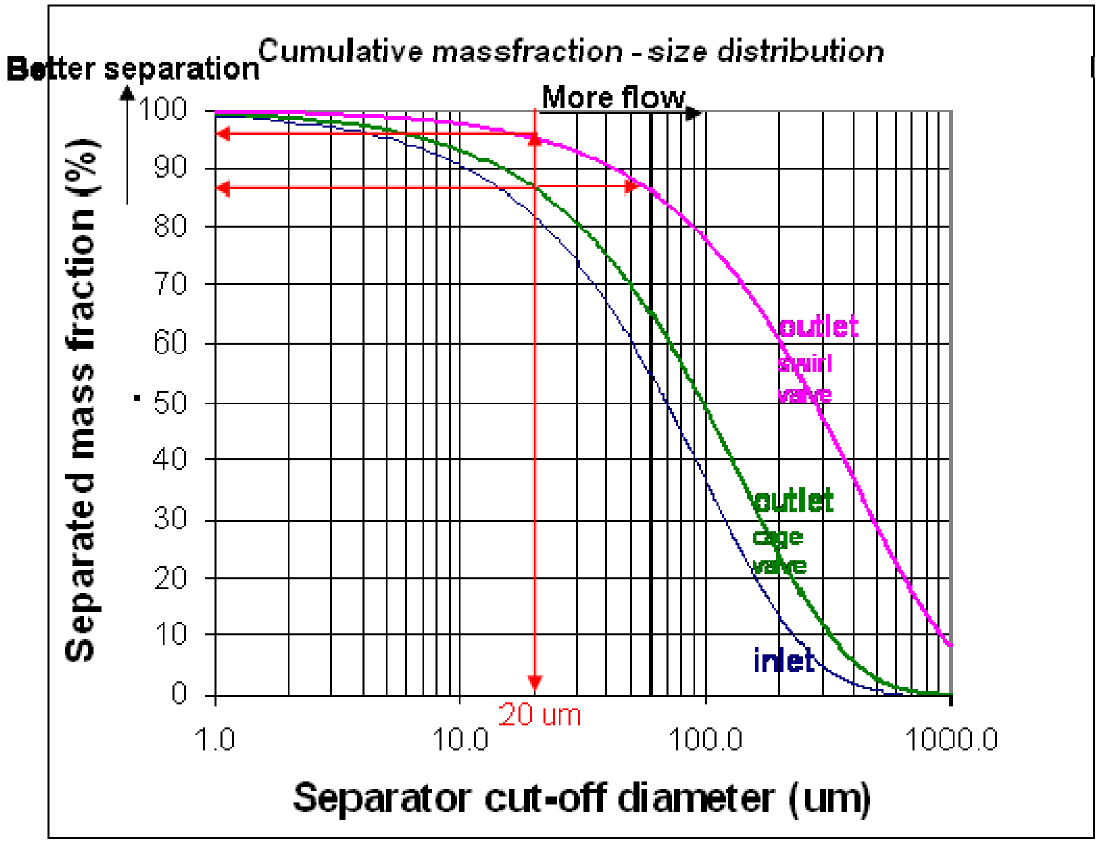


**Figure 3: Separated liquid fractions for a conventional cage valve (green) vs. SWIRL cage valve (pink)**

**Figure 3** details three cumulative size-distribution curves. The blue curve represents the size-distribution at the inlets of both valves. The green curve is the size-distribution at the outlet of a conventional cage valve whereas the pink curve presents the size-distribution at the outlet of the SWIRL valve. By applying a cut-off diameter of 20 micron for a SMSM separator (source: Sulzer), it can be concluded that the

SWIRL valve will improve the separation efficiency from 88% (using a normal cage valve) up to 98% (using a SWIRL valve). Alternatively, applying a SWIRL valve allows operation of the separator vessel beyond its design maximum (i.e. the cut-off diameter of the separator may reduce from 20 micron up to 60 micron while maintaining 88% separation efficiency). Another important observation is that the relative improvement obtained with a SWIRL valve is larger when the cut-off diameter of the separator train is high (> 50 micron). This is also the case if the liquid fraction (according to the inlet size-distribution) is dominated by small droplets (e.g. lean feed gas). In cases where filter cartridges (e.g. PECO type) are applied in a LTS separator train to catch the micron size droplets, the SWIRL valve will reduce the liquid load of the filter separator, thereby reducing the pressure drop and/or preventing liquid breakthrough (flooding) of the filter package.

## Field tests at NAM Opende Oost (The Netherlands)

A field trial was performed during September – November 2008 with a SWIRL valve applied as a JT-choke in a LTS train at the NAM Opende Oost location. Due to the fact that new production wells came on stream in September 2008, feeding the Opende Oost production facility, the plant capacity (with an operational maximum of 600,000 $Nm^3$/day) became the constraining factor. As the operator was aiming to achieve a flow rate larger than 670,000 $Nm^3$/day, the NAM selected Opende Oost as the preferred test location for the SWIRL valve (see **Figure 4**).


**Relevant plant data:**

- Feed pressure = 99 bar (nominal)
- Max. design capacity = 0.67 $10^6$ $Nm^3$/d
- Cold separator data:
  - Vertical SMSM separator
  - Operating temp. -18 °C (nom.)
  - Operating press. 68 bar (nom.)
  - Operating gas flow 0.6 $10^6$ $Nm^3$/d (nom.)
- Export specification
  - PHLC specification = 5 mg/Nm3 @ -3 °C
  - HC d.p. = -3 °C @ 27 bar
  - Water dew point = -10 °C @ 70 bar
- Current operating limits: max. flow <650,000 Nm3/d to avoid off spec and excessive DEG carry-over!

**Figure 4: The NAM Opende Oost Gas Processing module**

The export gas quality was monitored during the test period using an online hydrocarbon dew-point analyzer (Type: Ametek) and a mobile GACOM unit, both provided and operated by Gasunie Netherlands. The latter method measured the liquid dropout (= Potential Hydrocarbon Liquid Content (PHLC) in mg liq. /$Nm^3$ gas) at -3 °C and 27 bar.

The traditional low-noise valve trim (Mokveld Labyrinth cage) was operated during the test period from the end of September to mid-October 2008. The SWIRL trim was operated from mid-October to the end of November 2008.

Mokveld JT valve (4")

Build in Swirl cage

**Figure 5: Change out of the valve trim to a SWIRL valve trim 14 Oct 2008**

From the test plan the following flow regimes were foreseen:

1. Nominal flow : 600,000 $Nm^3$/day
2. High flow case : 650,000 $Nm^3$/day (design maximum)
3. Low flow case : 100,000 $Nm^3$/day
4. Ultimate flow case :> 700,000 $Nm^3$/day

The performance measurements are presented for each flow case.

## Test case 1: Nominal flow: 600,000 $Nm^3$/day

| | Labyrinth trim | Swirl trim |
|---|---|---|
| ΔP [bar] | 29.5 | 30.0 |
| Cold separator P [barg] | 62.7 | 63.1 |
| Cold separator T [barg] | -19.6 | -19.9 |
| PHLC [mg/Nm3] | 0.15 | 0.03 |
| Bovar [°C @ 27 bar] | -7.0 | -8.1 |

**Table 1: Performance measurements @ 600,000 $Nm^3$/day**

From the above table it can be concluded that both tested valves were within the hydrocarbon export specifications, although the SWIRL valve performance showed a slightly enhanced separation. **Figure 6** and **Figure 7** shows that the number of PHLC peaks was significantly less during the SWIRL valve test period.

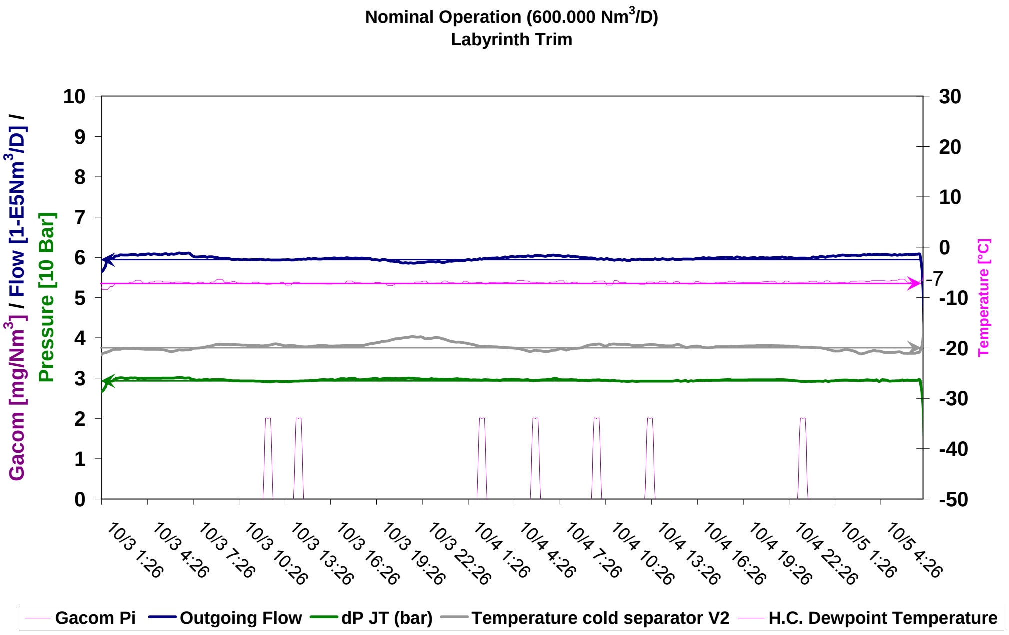


**Figure 6: Performance data conventional valve trim @ <u>600,000 Nm$^3$/day</u>**

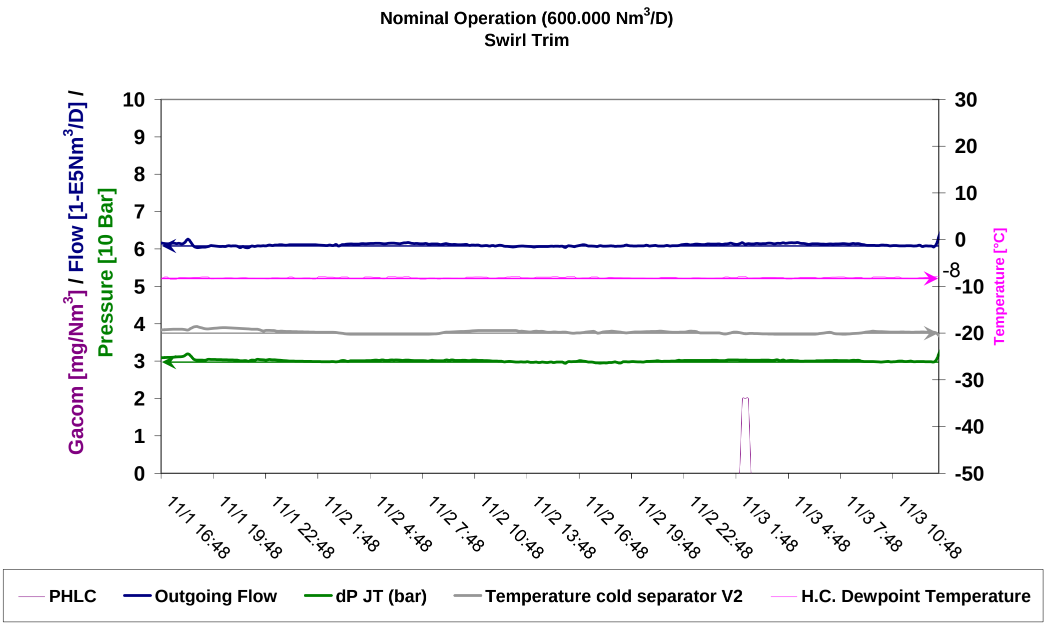


**Figure 7: Performance data SWIRL valve trim @ <u>600,000 Nm$^3$/day</u>**

## Test case 2: High flow: 650,000 Nm³/day

| | Labyrinth trim | Swirl trim |
|---|---|---|
| ΔP [bar] | 33.0 | 33.7 |
| Cold separator P [barg] | 63.7 | 64.0 |
| Cold separator T [barg] | -20.4 | -20.6 |
| PHLC [mg/m3] | 0.80 | 0.50 |
| Bovar [°C @ 27 bar] | -2.0 | -8.0 |

**Table 2: Performance measurements @ 650,000 Nm³/day**

The table above shows that the hydrocarbon dew point of the conventional labyrinth trim exceeded the export specification. It was therefore decided not to increase the flow any further with the labyrinth trim. The SWIRL valve trim showed a steady low dew-point reading. **Figure 8** shows that with the Labyrinth valve, the hydrocarbon dew point increased by 5 degrees to -2°C at 27 bars whereas the GACOM showed 7 measurements in excess of the specification of 5 mg/Nm³. It was further observed by the NAM operators that the glycol make-up rate increased when operating at this flow rate. However, **Figure 9** showed that by applying the SWIRL valve at 650,000 Nm³/day, the hydrocarbon dew point remained at -8 °C. In this case the GACOM only showed 2 excursions above 5 mg/Nm³ (of which 1 could be traced to a clear process upset).

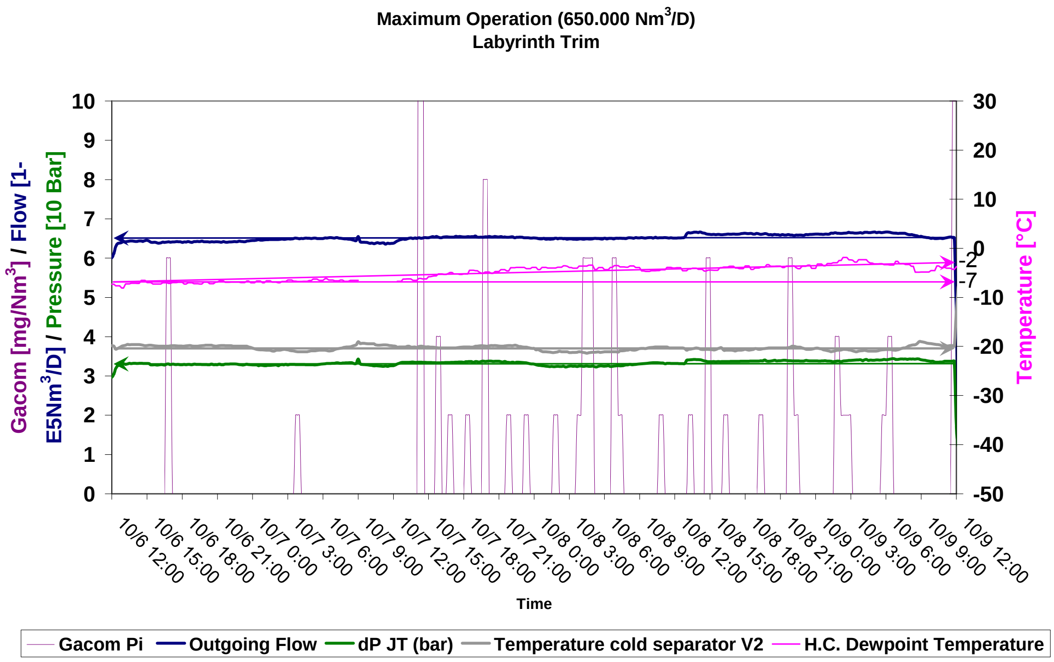


**Figure 8: Performance data conventional valve trim @ 650,000 Nm3/day**

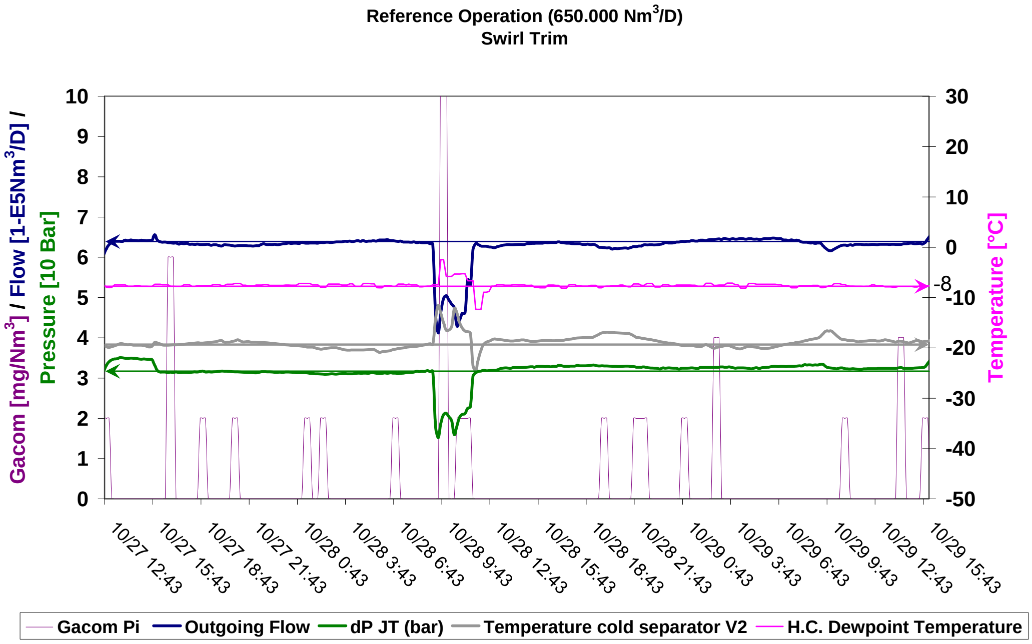


**Figure 9: Performance data SWIRL valve trim @ 650,000 Nm3/day**

## Test case 3: Low flow: 100,000 Nm$^3$/day

| | Labyrinth trim | Swirl trim |
|---|---|---|
| ΔP [bar] | 21.4 | 19.6 |
| Cold separator P [barg] | 63.3 | 62.6 |
| Cold separator T [barg] | -18.1 | -17.6 |
| PHLC [mg/m3] | 0 | 0 |
| Bovar [°C @ 27 bar] | -8.0 | -8.3 |

**Table 3: Performance measurements @ 100,000 Nm$^3$/day**

From the above table, and **Figures 10 and 11** below, it can be concluded that, for the turndown case, both valves are operating within the export specifications. As expected, the differences in performance in this low-flow regime are negligible.

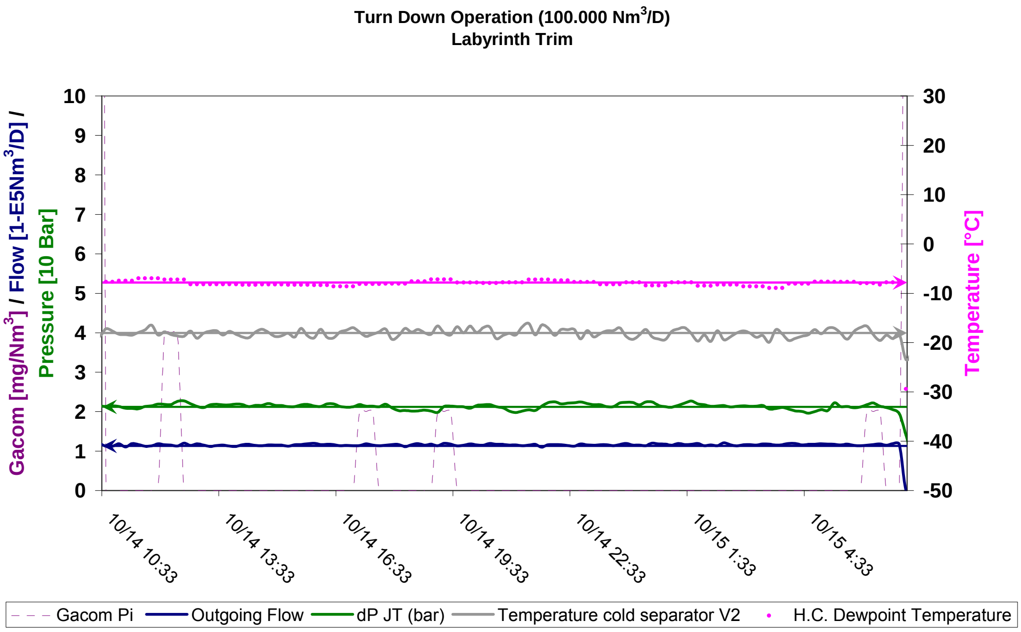


**Figure 10: Performance data conventional valve trim @ 100,000 Nm$^3$/day**

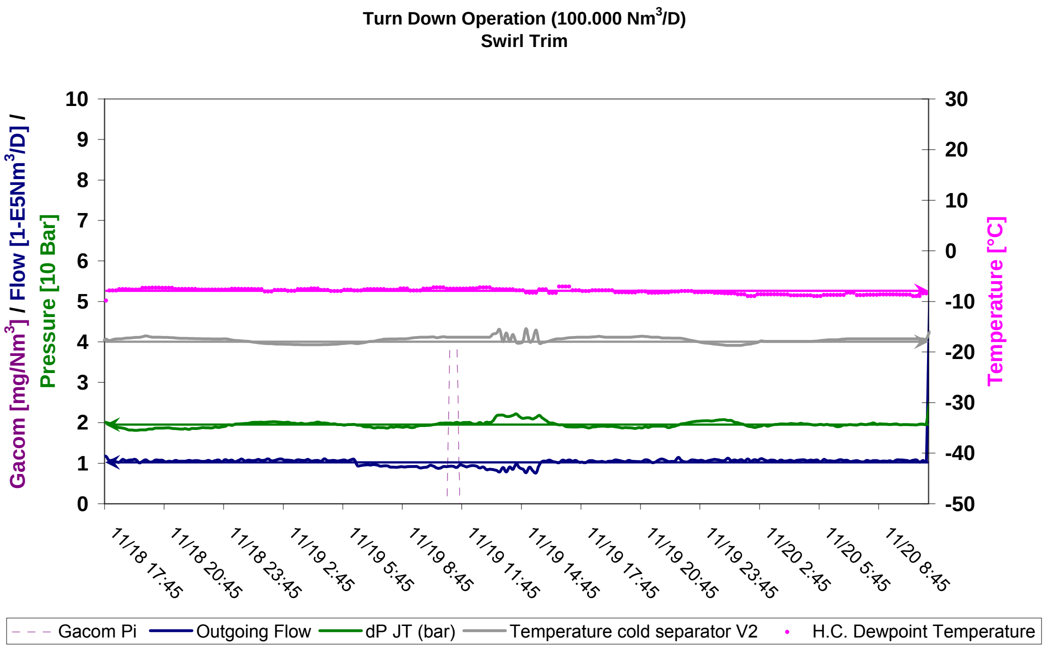


**Figure 11: Performance data SWIRL valve trim @ 100,000 Nm$^3$/day**

## Test case 4: Ultimate flow: 720,000 Nm$^3$/day

| | Swirl trim |
|---|---|
| ΔP [bar] | 25.3 |
| Cold separator P [barg] | 64.2 |
| Cold separator T [barg] | -18.7 |
| PHLC [mg/m3] | 0.17 |
| Bovar [°C @ 27 bar] | -7.5 |

**Table 4: Performance measurements @ 720,000 Nm$^3$/day (SWIRL valve only)**

The table and **Figure 12** (below) demonstrate that the SWIRL valve was able to continuously operate at a flow rate of 720,000 Nm$^3$/day whilst staying well within the hydrocarbon export specifications. The NAM operators experienced no increase in glycol consumption when operating at this high flow rate.

The flow rate was increased to 735,000 Nm$^3$/day, the maximum possible rate of the fiscal export flow meter, whilst still meeting export specifications. It was felt that this rate could have been increased further.

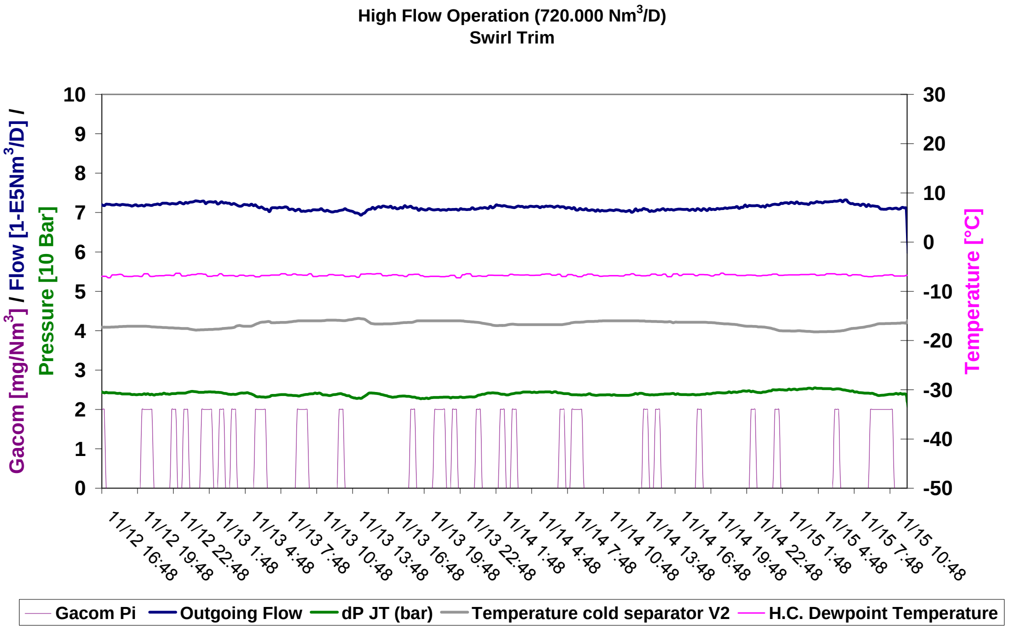


**Figure 12: Performance data SWIRL valve trim @ 720,000 Nm3/day**

## Test case 5: High cold-separator temperature

The final performance test was a trial to increase the cold-separator temperature whilst operating the SWIRL valve at 710,000 $Nm^3$/day, until the hydrocarbon export specifications were exceeded. The results are shown in **Figure 13** below.

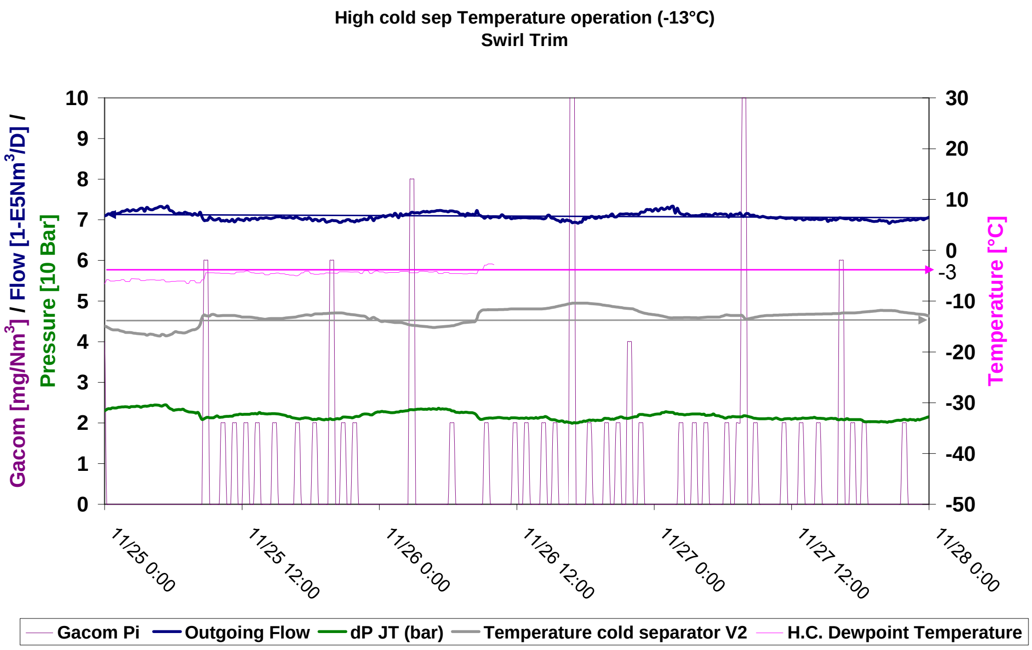


**Figure 13: Performance data SWIRL valve trim @ 710,000 Nm3/day and 7 °C higher cold sep T**

It is concluded that the cold-separator could be operated at temperature of 4 – 5 °C higher when using the SWIRL valve trim, compared to the conventional valve (which requires the cold separator to be operated at -19 to -20 °C). Translation of the allowable temperature increase of the cold-separator to an allowable reduction of the feed pressure resulted in a 3 to 4 bar lower feed pressure for the NAM Opende Oost facility. This will have a positive impact by allowing the deferral of planned compression installation, thereby allowing fuel cost savings.

## Noise level measurements

As part of the test program, the noise levels of the SWIRL valve were measured and compared to the measured noise levels of the Labyrinth trim (low noise), as well as with a rotating-disc choke (type: Tyco). All noise measurements were carried out at the NAM Opende Oost plant.

**Figure 14** (below) shows the noise measurement (at 1 m distance) for the 3 different JT chokes.

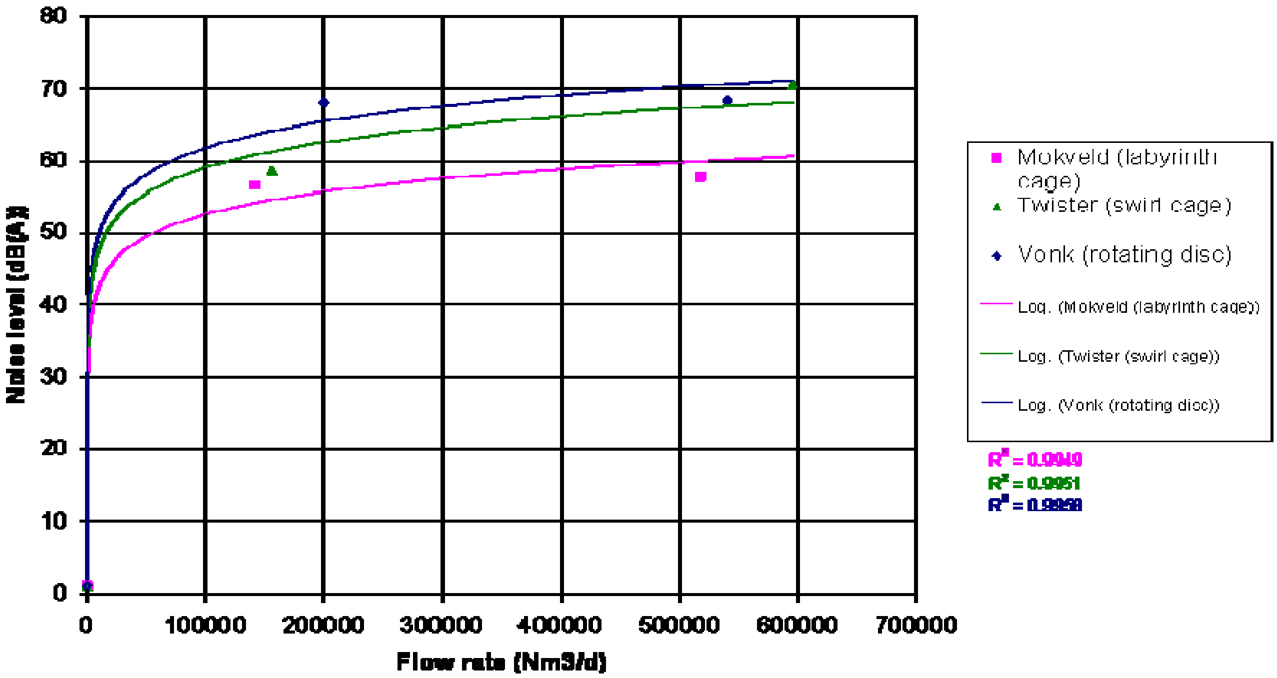


**Figure 14: Noise level data 3 types of valve trims operated at NAM Opende Oost (1 m distance)**

The conventional low-noise trim (i.e. Labyrinth case of Mokveld) is the most silent valve. The SWIRL valve produces a noise level close to a (standard) Tyco rotating disc choke. However, Twister BV is confident that further design refinements are possible that will reduce the SWIRL valve noise levels.

## Conclusions

A thorough field test of the Twister SWIRL valve has proved to be successful in both reducing the hydrocarbon dew point of the export gas, and in debottlenecking the flow capacity of the Opende Oost Production facility.

The application of the Twister SWIRL valve allowed the plant capacity at NAM Opende Oost to be increased by 20%, the pressure drop over the JT valve to be reduced by 20%, and a reduction in glycol consumption.

Due to the excellent performance and the resulting incremental production, NAM has decided to continue to operate the SWIRL valve at the Opende Oost facility for an undetermined period.

The Twister SWIRL technology applied as a JT choke in LTS gas processing plants is now proven; and can be used to improve plant dew-point specifications or to lower feed pressures.

Future Twister BV design and development work will be aimed at further reducing noise levels, in determining the minimal required pressure drop for a SWIRL valve to work (currently 10% of feed pressure) and plus oil-water/condensate-water separation.

## References


1. M. Betting, ***"Throttling valve and method for enlarging liquid droplet sizes in the throttled fluid stream"***, Patent publication no. WO2006070020A1.
2. R. van Bakel, ***"Test report SWIRL valve trial NAM Opende Oost location",*** 22 Dec 2008.


## Abbreviations

HC : Hydrocarbon

JT : Joule-Thomson

LTS : Low Temperature Separator

NAM : Nederlandse Aardolie Maatschappij

PHLC : Potential Hydrocarbon Liquid Content

SMSM : Schoepentoeter Mistmat Swirldeck Mistmat