Inferential Slug Control System Field Trial Summary

by

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INFERENTIAL SLUG CONTROL SYSTEM

OFFSHORE FIELD TRIAL SUMMARY REPORT

1. EXECUTIVE SUMMARY

This report documents the results obtained from a series of successful field trials undertaken to test the functionality of the Inferential Slug Control (ISC) technology (slug detection and control system) developed by Cranfield University. The tests were conducted between January and April 2011 on a live offshore oil production platform in the North Sea (due to the commercial confidential agreement, we cannot disclose names of the platform and its operator in this report).

2. CONCLUSION

The field trials conducted demonstrated that the ISC is a robust and efficient system which effectively detects and attenuates hydrodynamic slugging in a real-time, active offshore production system. It also demonstrated that it is adaptable to cope with significant flow assurance and well operation changes. The trials also demonstrated the ISC's ability to reduce the pipeline pressure and increase production.

3. BACKGROUND

For the past 10 years, Cranfield University has been developing a slug detection and control system, namely the ISC. The system uses multiple available measurements on a platform to detect the formation of slugs within a pipeline or riser, and to actively, in real time, operate a control valve to attenuate the slug before it enters a sensitive part of the process system. By incorporating such a device it is expected that:

- Fluctuations caused by slugging flows will be suppressed resulting in a stable and safe operation of offshore production systems.
- An immediate increase in production can be realised because of the reduced average pipeline pressure after slugging is attenuated.
- Separator and other equipment will be protected from the destructive kinematic effects of the slug.

- New-field production systems can be significantly reduced in size (cost) as slug accommodation will not be necessary.
- Existing field production systems can extend their production life because of the reduced pipeline pressure.

To validate the design of the ISC as a system qualified for field use, the system, which has undergone successful trials at the Multi-Phase Flow Laboratory at Cranfield University, requires successful completion of field trials on a live offshore platform. This report catalogues the trials undertaken and highlights the results and validation of the system as a field-ready product.

4. FIELD TRIALS DESCRIPTION

4.1. Offshore Production System Description

The offshore production system used to undertake the ISC trials is highly productive with a number of high pressure wells. A long tie-back pipeline over 32 km long connects two remote well-head platforms in series to a 100m high riser on the main processing platform where the ISC was installed. The slugging flow being experienced at the main process platform primary separation system was initially classified as severe slugging, but this was ascertained through the trials to be hydrodynamic slugging with average slugging cycles at about 2-3 minute intervals. In full operation, the superficial velocities are about 1 m/s and 5 m/s for liquid and gas respectively. To deal with such slugs, the slug control valve, installed at the riser outlet upstream of the first separator, is manually choked to a high choke setting which results in a large pressure drop in excess of 10 bar with a consequential restriction to flow. Even with such significant choking under normal operation, the flow condition of the pipeline fluctuated significantly, causing the riser top pressure to vary by approximately 2 bar. On the other hand, this long distance tie-back resulted in a large time constant to settle down to any operational changes, which was currently being experienced as 2-3 hours for gas flow and as long as 20 hours for liquid flow. As such, the primary goal of the trials was to reduce the pipeline flow fluctuations to a level significantly lower than that under manual choking operation and to reduce the pipeline pressure to improve productivity. These operational improvements needed to be maintained for at least 24 hours to be validated as a successful and effective trial of the ISC system.

4.2. ISC System Set-Up

The ISC system was implemented as a MATLAB program installed on a dedicated laptop, which was connected to the site main control system through a digital network connection. The network connection protocol was the OPC Link when the ISC was tested in the laboratory. For the field trials, it was through a SQL database server. For every 3-second, the ISC will communicate with the site main control system to get 12 specified measurements and calculate the optimal valve choke position based on these measurements, then send the result to the site main control system to adjust the choke valve accordingly. The ISC used the same choke valve, which was used for manual operation.

4.3. ISC Slug Control Trials Results

4.3.1. Trial 1

Prior to initiating the ISC, fixed choking results were collected overnight in order to provide a baseline from which to assess ISC controlled production system results. Upon initiation of the ISC system, the ISC choke control setpoint was gradually adjusted over a 4 hour period until the measured riser head pressure fluctuation was reduced from 2.0barg to 0.5barg. At this setting the ISC successfully maintained the riser head pressure variation to within 0.5 barg for a 6 hour period, after which the test was stopped due to a platform shut down. The results of this brief test are illustrated Figure 1 below.

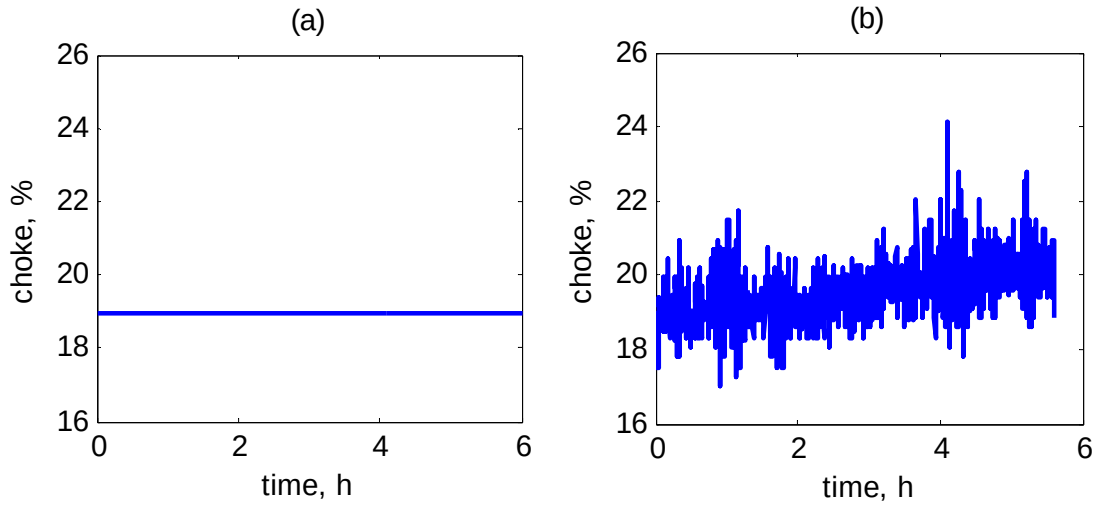


Figure 1a Riser Head Choke Position (a) Fixed; (b) Under ISC Control

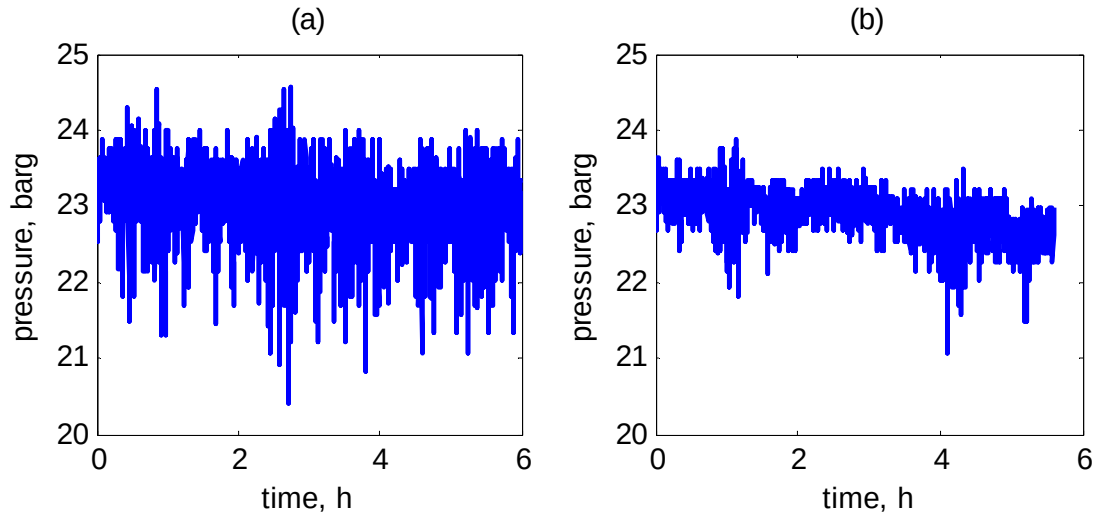


Figure 1b Riser Head Pressure (a) Fixed; (b) Under ISC Control

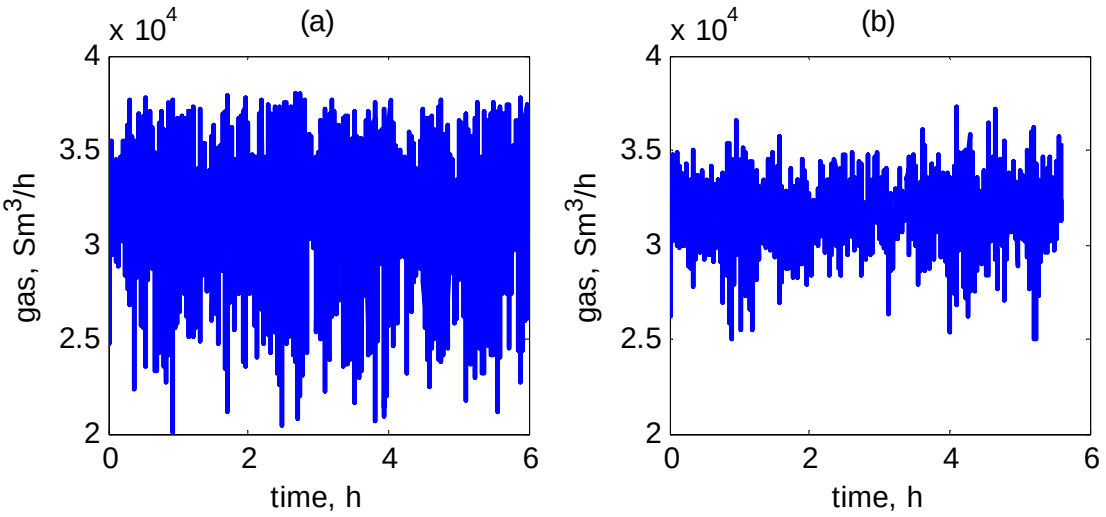


Figure 1c Separator Gas Flow (a) Fixed; (b) Under ISC Control

4.3.2. Trial 2

Upon resumption of production, testing of the ISC system was resumed and ran continuously (without interruption) for 42 hours. However, during the first 12 hours of resumed production, a number of process events, which caused significant production flow perturbations was experienced, through which the ISC system continued to operate effectively, maintaining the riser head pressure fluctuations to within 1barg through the trial period. Descriptions of these events follow:

Start-Up

As can be seen from Figure 2a Riser Head Pressure, the ISC system stabilised flow to maintain pressure fluctuation within 0.5barg after approximately 1.5hrs.

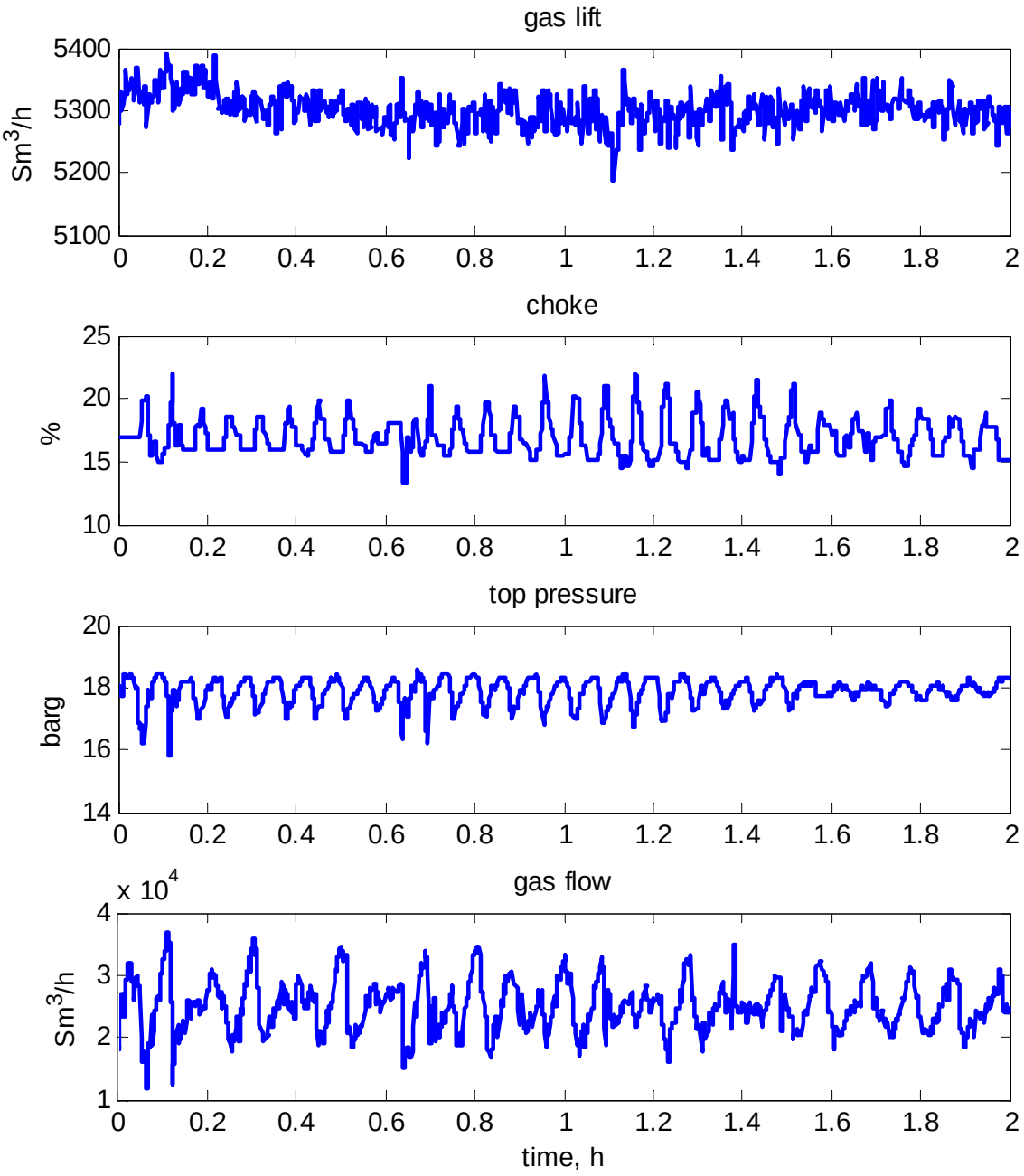


Figure 2a. Start-up.

Hour 2

After approximately 2.5 hrs production, gas lift was lost due to a compressor shut-down, which caused a reduction in the production rate with a corresponding reduction in riser head pressure. Throughout this event, the ISC system tracked the flow perturbation and continuously maintained stable operation until gas lift was resumed. This event is illustrated in Figure 2b.

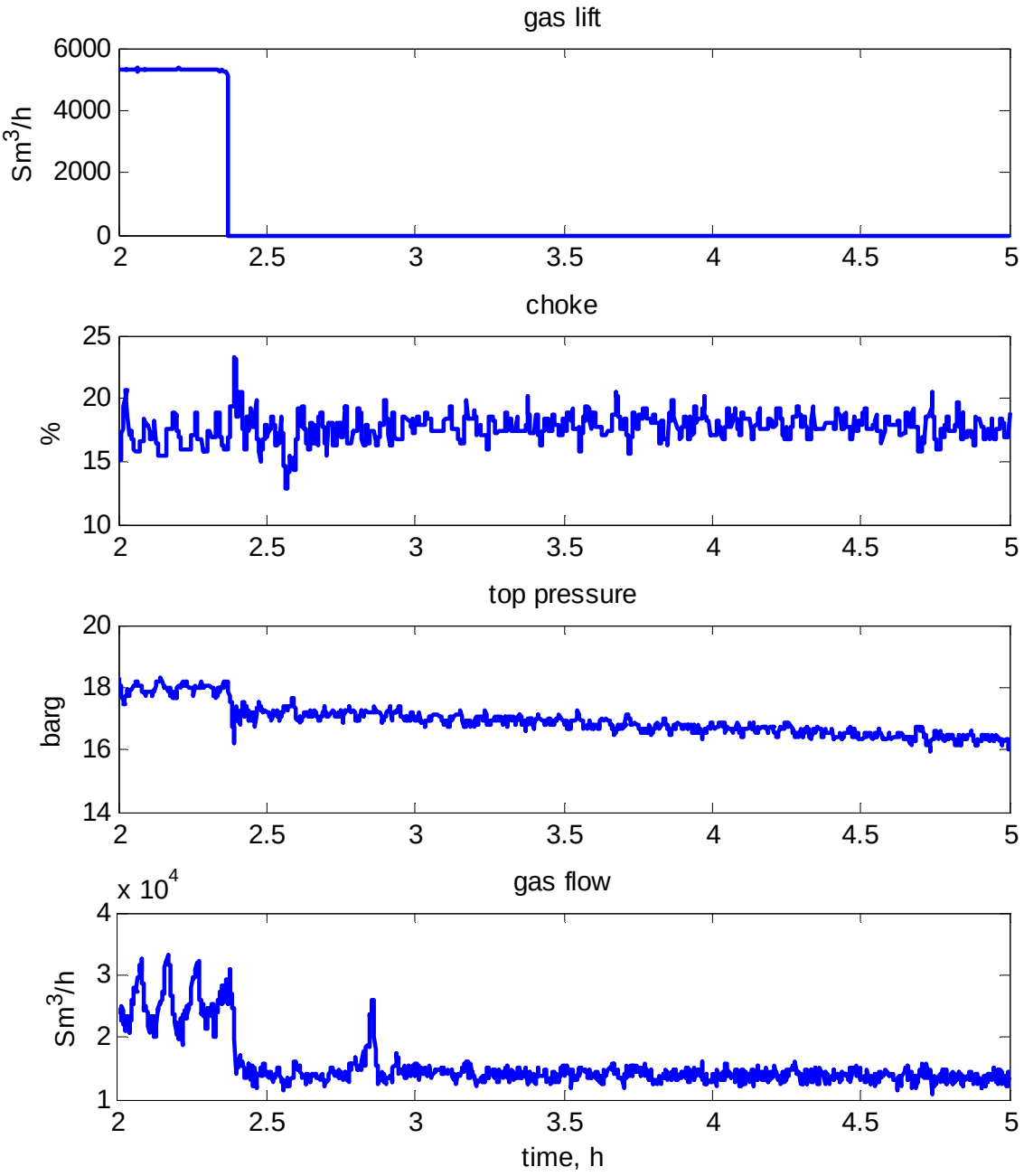


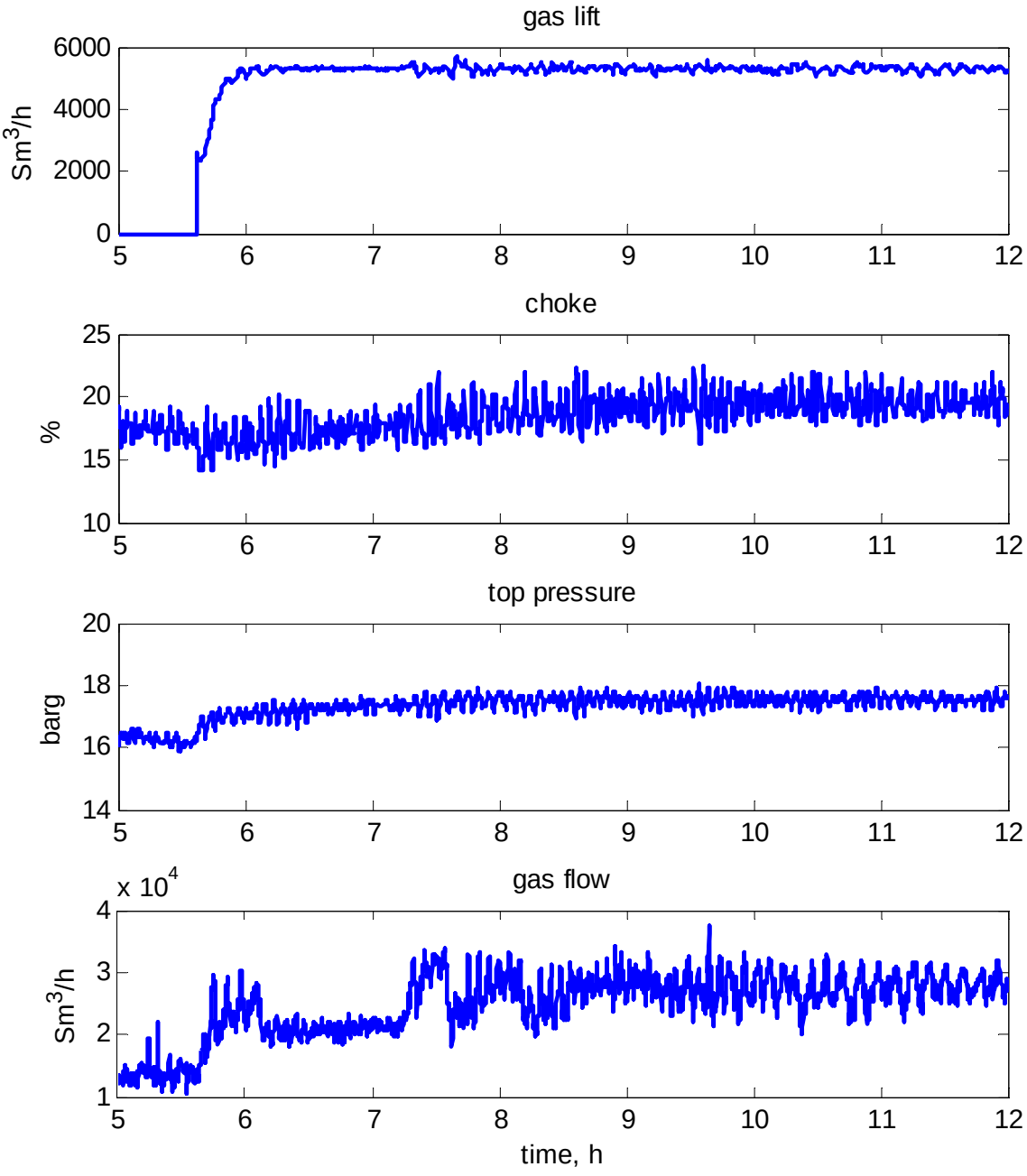
Figure 2b. Compressor shut-down event.

Hour 5

After approximately 5.5 hrs, the compressor and lift gas were resumed. The ISC again successfully dealt with this event without any problem as illustrated in Figure 2c.

At about 6.5 hrs, there was a well start-up in the neighbouring field which connected to the common import flowline and process separator. This caused a disturbance in separator pressure, but again, the ISC system successfully tracked this perturbation, kept the system

in stable operation and maintained the riser head pressure to within 1barg. This event is illustrated in Figure 2c.



Figur 2c. Compressor resume event.

Hour 7 to 42

During the remainder of the testing period, the ISC system continued to function normally, maintaining the riser head pressure fluctuations to within <1barg.

4.3.3. Post Test Production Analysis

At the conclusion of the trials, an analysis of the platform Daily Production Reports showed that during the two trial periods, there was an increase in production of 9.6% which can be attributed to the effectiveness of the active ISC system. Unfortunately, documentary proof of this cannot be cited due to the Operator confidentiality requirements.

5. TABLE OF ACRONYMS

ISC	Inferential Slug Control, a Cranfield invention.
OPC	OEL (Object Linking and Embedding) for Process Control, a network protocol for process control.
SQL	Structured Query Language, a database management system.
MATLAB	A software tool for scientific computation.