NEW WELL SURVEY METHODS MINIMISING TECHNOGENIC ENVIRONMENTAL IMPACT

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1. Background
The principles of sustainable development adopted by IGU on the 23rd WGC are the foundation of the environmental management. They seek for maximal efficient hydrocarbon production and ecological safety in gas field development and operation. A lot of problems should be solved to provide ecological safety, the major one being reduction of greenhouse gas emission, which is rather tightly associated with the main field development technological processes. Let us prove that it is true.

Reliable information concerning field development status is one of the main issues of producing companies. This is provided by periodical experimental activities such as standard gas dynamic well surveys (GDS) during the steady-state filtration modes. Their aim is to determine well parameters and humidity content in well production.

As a rule, these experimental activities are accompanied by partial gas flaring and discharge in the atmosphere of production gas including greenhouse gases, which impact flora and fauna accordingly.

So, one of the pivotal goals of gas industry is to improve known or to develop new well surveys minimizing or even completely eliminating pollutant emissions.

In the Far North of the Western Siberia - the region of the main Russian gas production supplying gas through the trunk pipelines to our domestic and European consumers - these goals become more complicated due to severe climate conditions, as well as high tundra sensibility to the technogenic impact. Destroyed land reclamation goes on extremely slow. That’s why all types of conducted works are planned so as to minimize technogenic impact on the tundra in the Arctic zone.

This paper covers practical solutions of the above mentioned problems.

2. Aims
To prove and implement new methods of gas dynamic well survey, providing reliable information about field development status with minimal technogenic impact on the environment in the Arctic zone of the Western Siberia.

To prove and implement new methods of well production humidity content control in rigorous conditions of the Siberian Arctic.

New methods should completely eliminate or minimize pollutant emissions during gas dynamic well surveys and product characteristic analyses (including fluid humidity) on the wellhead.

The second aim: gas required for surveys with great gas consumption should remain in pipeline and be delivered to the end consumer. At the same time the accuracy of conducted measurements and their results processing methods accuracy should not go down and be consistent with the field development requirements within its operation life cycle.

3 Methods
a. Gas dynamic well surveys
Production wells at the great and giant oil-gas-condensate fields of the Far North of Siberia are built by cluster directional drilling. About 15 wells are constructed on one site; their gas production can exceed 2 mln m³ per day. Due to such well concentration the number of sites required for their construction and roads for their servicing during field development is reduced. Thereby technogenic impact on the tundra is decreased accordingly.

Taking into account this feature of field development Gazprom specialists have developed and patented a method of group gas dynamic surveys for gas well clusters entirely eliminating popping of gas and flaring [1, 2]. According to this method wells are grouped in pairs with maximum overlapping areas of external
reservoirs boundaries. Wells from the selected pair are included in different groups. Two well groups consisting of same-name pairs are surveyed simultaneously. One group is tested in reverse motion mode with production rate diminishing until the full stop. The other one is tested at the same time with the first one, but in forward motion mode with production rate acceleration up to the maximum permissible volume. Then the rate directions in both groups are changed to the opposite. All surveys are conducted on wellheads connected to the gas gathering system in order to eliminate gas or its burning product emission impact on the environment and human resources. Telemetry system controls technological parameters while surveying.

In the process of testing production rate of each well pair and the total production rate of well cluster are controlled with their values being kept close to the constant ones. Continuity of total production rate of wells with maximum interaction under combined actions enhances stabilization of flowing reservoir pressure in well drainage zone. Each of the forward motion mode corresponds to the reverse motion one, thus the data reliability raises noticeably. Wells can be surveyed at their simultaneous performance for intra-field gas gathering system in all possible modes including maximal permissible one without reduction of total gas flow rate in the cluster and without gas emissions. Thus gas required for gas-dynamic surveys remains in field pipeline and is supplied to the end consumer.

The main advantage of these surveys is possibility to process all results of simultaneously made measurements on well cluster, gas gathering line inlet and outlet to the valve station by sensor system Teletrans 3508-30C. After processing we have a full set of system productive parameters: formation – well – gas gathering system (productivity factor, well hydrodynamic resistance factors and well, binding and gathering line heat loss). This data set permits to model thermodynamic operation mode of gas-gathering systems with regard to the flow phase pattern (PIPESIM Compositional Model) and forecast hydrate formation.

Developed method of group gas dynamic surveys of gas and gas-condensate wells not only improves the accuracy of measurements achieved through the summation of joint well performance in gathering line, but considerably reduces work hours required for survey implementation by introducing telemetry systems. Production well operation is controlled on-line at different production rates levels. The data obtained determines productive parameters variations and is used to plan gas dynamic surveys.

Fig. 1 shows gas dynamic well cluster survey conducted in Zapolyarnoye field.

This technological method was awarded the Environmental Technologies Award by Russian Ministry of Mineral Resources as being the best ecological project in 2008.

b. Stand-alone telemechanic system for non-electrified gas well clusters

Telemetry systems provide for above mentioned goals, they include measuring devices for flow rate measurement, flow control operation units, devices for hydrate formation inhibitor (methanol) injection control and set of signal processing measures and information transmission to the control unit. Conventionally, telemechanic systems use centralized power supply (power transmission facilities which are to be built during field development). Construction and maintenance of power supply systems for well clusters form
additional negative environmental impact on tundra ecosystem within its whole life cycle. It is obvious that in the Far North of the Western Siberia it is not the best solution to assure environmental safety and to minimize ecological risks for tundra ecosystem.

When developing Aneryakha and Kharvuta sites of Yamburg oil-gas-condensate field the specialists of Gazprom and scientific-production association Vympe l faced the challenge to create stand-alone telemechanic system for gas well clusters. While solving the problem it turned out that in the world there are no any approved technologies for its complex realization in such inclement climatic conditions of the Russian Far North.

To develop this system a number of specific technical devices have been developed and approved in production conditions while developing Aneryakha site in 2003 – 2006. These specifically designed devices and industry-standard technical equipment served as a base for development and implementation of telemechanic system at Kharvuta site in 2007, which solves the problem in complex.

Technical and operational parameters of new developed and industry-standard technical equipment used in this system are not inferior, but to a large extent excel traditional ones made by leading Russian and foreign companies. The system is protected by RF patents. [3, 4]

For the first time in the world the following problem was solved: information about every well operation mode is generated and transmitted to the upper levels of control from non-electrified clusters which are operated in polar nights and cold weather conditions of the Far North. As a result of the work a complex of progressive scientific and technical developments, design and system engineering decisions was used to create price and operation parameters competitive telemechanic system (Fig.2). This solution completely meets IGU Principles of Sustainable Development.

The system includes new devices such as:
- wear resistant flow meter for gas wells with self-contained power supply designed for three years of operation;
- control valve with low power consumption electric drive;
- low power consumption inhibitor (methanol) injection system;
- low power consumption sensor-indicator of sloughing of sand and water;
- low power consumption self-contained power supply master controller;
- thermoelectric generator;
- thermal protection ensuring functionality of low power consumption micro-electron devices and operation of rechargeable battery pack;
- software.

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The cluster and control sets comprise also serial equipment: wind generators, solar batteries, rechargeable batteries, controllers, processing and transmission and display devices.

Such types of generating devices as: wind power generator (uses wind energy), solar battery (uses sun light energy) (Fig.3) and thermoelectric generator (uses a temperature difference between produced gas and ambient air) (Fig.4) have been chosen as power supply sources. This set of sources operating simultaneously produces energy for year-round system operation in conditions of seasonal and current stochastic environmental changeability. Reserve rechargeable batteries pack is used for the same reason.

Specific cluster set power supply controller controls battery recharge mode (provides the most effective energy consumption mode) and monitors power supply margin.

One of the most challenging problems solved during system development was stabilization of temperature conditions for cluster equipment operation. Cluster set equipment could not be subjected to outdoor conditions, because the Russian northern fields ambient temperatures varies from –50 °C to +40 °C. The problem have been solved by underground placing of cluster set equipment just directly on the well cluster. Installation pit is constructed on the gas well cluster and cluster set equipment is placed inside it. The pit is covered by thermo-insulating cap for additional thermo isolation and precipitation protection. A mast is fixed close to the pit for antenna-feeder device, solar battery and wind generator mounting (Fig.3). Thermoelectric generator is installed directly on the gas pipeline (Fig.4) delivering gas from gas wells to the gas treatment plant.

Information from all gas well clusters is transmitted to the control center and displayed on the duty shift computer workstation. Production well operation mode is controlled from the same station.
Telemechanics system of gas wells group of gas field Kharvuta, Yamburg

- Thermoelectric source
- Gin pole
- Solar generator
- Wind-powered generator
- Antenna-feeder device
- Mounting modulus
- Block of electronics for wells group
- Spare unit of power supply for wells group
- Methanol addition system
- Gas flowmeter "HyperFlow"
- Production Rate Regulator
- Sensor of sloughing of sand and fluid
- DCP-AK
- All-up sensor with calculator of discharge rate "HyperFlow - 3Pm" model 006

Fig. 2
Fig. 3 Mast with the mounted equipment

Fig. 4 Thermoelectric generator on the gas pipeline
Operation staff technical equipment is designed to integrate telemechanics system with related automatic control systems and systems of higher level. At the same time the system provides gas dynamic surveys of gas well clusters with minimal personnel presence on the well sites. Measurement automation ensures surveys in such seasons when human presence in tundra is not advisable because of the extremely negative impact on the environment.

c. Humidity and other well fluid characteristic control

The presence of permafrost (up to 500 m) should be taken into consideration while operating gas and gas condensate fields in the Far North regions. The specified requirements for technological mode of well operation are conditioned by this fact. The mode should provide for efficient combination between well flow rate, temperature and hydraulic losses while gas-water and gas-condensate mixture travel from formation to the wellhead.

On the one hand, a high pressure on the wellhead provided by low consumption improves the operation of gas gathering and gas treatment systems. On the other hand, slow rate of upflow worsens liquid and mechanical impurities bearing-out. Permafrost zone exposes a danger of mixture cooling down to the hydrate formation temperature which may cause malfunction.

Increasing consumption raises gas temperature at the wellhead and at the same time increases depression load on the formation. It may cause its destruction or if we deal with formation with stable low penetration, we may encounter liquid phase separation in bottom hole formation zone and well bottom. Consequently the resistance to the formation gas flow grows, causing bubbling and collector liquid impregnation in the lower perforation interval. As a result well efficiency gets down.

It is necessary to monitor local water and gas condensate content in its liquid phase in well production at different operation modes to solve the problem. This data is the prerequisite for setting optimal consumption rate, which ensures stable operation of operating well stock and gas gathering systems. Special measurements determining water content in well production make it possible to conduct water protection measures in time and select optimal well operation mode assuring its stable work and minimizing water production i.e. flow rate prolonging maintenance-free well operation.

Today water content in well production is determined mainly by separation technologies which cause gas popping. Fig.5 presents mobile low-tonnage separator used for these measurements.
In summer time its transportation in tundra is not allowable because it destroys soil cover which remediation may not happen.

We addressed a challenge solving the problem of humidity control and monitoring other well fluid parameters with no gas popping and utilization of bulky equipment destroying tundra surface. We have developed special methods and equipment protected by RF patents [5, 6, 7]. These methods makes it possible to determine gas humidity, water presence in drop phase and conduct express analysis of water mineralization by resistivity metering.

At the first stage thermal hygrometer with sorption-capacitive sensitive element was used. Its operating principle is based on dependence of polymer moisture-sensitive layer dielectric permittivity on environment humidity. The temperature is measured by silicon digital sensor. Field tests of this compact unit had been carried out in 2002-2003 in Yamburg and Eastern-Tarkosale fields. More than 500 well have been surveyed and more than 900 measurements have been conducted. Concurrently all drawbacks of the developed method were being revealed and analyzed.

At the second stage there have been developed a technique to determine specific water quantity in drop phase of well production. It is calculated by absolute density of produced gas mixture with dropping liquid $\rho_{\text{mix}}$ and net gas density $\rho_{\text{dry gas}}$ from:

$$\varphi = \frac{\rho_{\text{mix}} - \rho_{\text{dry gas}}}{\rho_{\text{mix}}} \times 100\%$$

Mixture density $\rho_{\text{mix}}$ can be easily calculated by pressure difference $\Delta P$, caused by the gas mixture column of specified height, its absolute pressure $P$ and temperature $T$. Having field data of net gas composition we can calculate net gas density $\rho_{\text{dry gas}}$ under the same pressure and temperature. Pressure difference was measured by specially designed system based on differential pressure gage. External design of this device and its last modification is shown in the Fig. 6.

**Fig. 6** Gas density gage (GDG) – general view: a) GDG-1; b) GDG-2.
More than 1300 surveys have been conducted by the equipment abbreviated GDG-1 (gas density gage) in Yamburg and Severo-Urengoi fields in 2004-2006.

Fig. 6 presents the latest modification of GDG-1. Its schematic diagram is displayed in Fig. 7.

Fig. 7 Schematic diagram of combined device designed to determine humidity content in well production.
In 2007 quite a new technique for humidity content monitoring has been developed using this device [5]. The device provides for improved and significantly more accurate measurements and presents absolutely new quality level. The main design features of GDG-1 and survey technology are following.

Operating chamber 1 is a hollow vertical cylinder of not less than 1.5 m height. Inlet 2 and outlet 3 pipelines (collectors) are thermo-insulated high-pressure pipes with shut-off-and-regulating elements 4. They regulate pressure and gas liquid mixture consumption in operating chamber and isolate it from gas line and atmosphere at measurement moment. Closed type heating element 5 located at the external wall of the operating chamber 1 heats the sample inside it and provides liquid evaporation from walls and bottom of the chamber. Operating chamber 1 and heating elements have thermo-insulating casing 13.

Sorption-capacitive sensors are on the upper and lower horizontal surfaces of operating chamber 1. They measure relative humidity of the tested sample. Sensors of absolute pressure 7 and temperature 8 are fixed at the top of the operating chamber.

Pulse tubes 9 are filled with calibration liquid. They connect differential pressure gage 10 with operating chamber 1. Differential gage is connected to the operating chamber in its top and bottom horizontal surfaces.

All sensor readings are processed in data processing unit 11 and recorded by the computer 12.

Survey technology. The device is connected to the wellhead gage seating in wellhead connection by pipeline 2. Shut-off-and-regulating elements 4 determine feed rate of gas liquid mixture through operating chamber 1 with preset absolute pressure providing its lowest fluctuations which are indicated by absolute pressure sensor 7 and differential pressure gage 10, in other words ensure device steady-operation mode. Then gas-liquid mixture is isolated in operating chamber by simultaneous shutting of shut-off-and-regulating elements 4 at the outlet 3 and inlet 2 collectors. After sample’s isolation the readings of sorption-capacitive elements 6 and differential gage 10 are controlled up to their full stabilization. Readings stabilization stand for mixture phase equilibrium in operating chamber. Further measuring is dependent on sensors 6 and 10 readings.

If sensors 6 readings are identical and register relative humidity less than 100 %, it means absence of drop moisture and survey is considered to be finished. Gas moisture content is recorded after sensor 6 reading, which assures higher-level precision of measurements as compared to sensor 10.

If sensor 6 in the bottom part of the chamber registers relative humidity equal to 100%, it means liquid condensate accumulated in it. In this case the sample is heated by heating element 5 to the full or partial vaporization of this liquid. This process is monitored by sensors 6 and 10 readings dynamics. If condensate liquid is completely vaporized the moisture content is determined by sensor 6 readings. Otherwise moisture content is calculated by gas density defined by hydrostatic method.

This measurement technology ensures maximum precision of wellhead gas humidity content estimate which is achieved by the combined measurement of moisture content in vapor and liquid phases. Sorption-capacitive elements can register absolute gas humidity at the level of 0.03 g/ m³. Liquid phase water content is calculated by gas density defined by hydrostatic method.

4. Results
The developed well cluster survey techniques applied for well cluster feeding gas to intra-field gathering system in all modes including maximum permissible do not reduce total cluster gas flow rate. Therefore during gas dynamic surveys the well cluster operates as usual and provides planned gas supply to the consumers. It means we don’t have to consume gas, planned as gas for own use to survey well. These techniques gave opportunity to prevent burning about 1 mln m³ of gas for every tested well and reduce greenhouse emissions accordingly.

It has been proved experimentally that the measurements can be performed with usage of telemetry system and without maintenance personnel presence at the controlled gas well cluster. Telemetry and telemechanics system for non-electrified well clusters have been developed and experimentally worked out. The system is powered by combined concurrently operational renewable energy sources (solar, wind and thermal). Thanks to its implementation construction of power lines to well clusters in Arctic conditions of the Western Siberia can be excluded resulting in reduction of technogenic impact on the vulnerable tundra ecosystem. System cost is by an order less than power line cost.

Initially, relative well fluid humidity control has been performed by the device based on digital sorption-capacitive sensor. Its operating principle is based on the dependence of polymer water-sensitive layer permittivity on ambient humidity. The surveys have been conducted under ambient air temperatures within -20 °C – +30 °C. Well survey duration was about 60 min. Field surveys have been carried out in 2002-2003 in Yamburg and Vostochno-Tarkosale fields. More than 900 measurements were realized in 500 wells.
Specific quantity of drop phase water in well production was determined by absolute density of gas and dropping liquid mixture, calculated by specifically designed unit. It monitors pressure differences in points arranged vertically in measuring chamber of GDG-1 device, absolute pressure and mixture temperature. In 2004-2006 in Yamburg and Severo-Urengoi fields more than 1300 surveys have been conducted by this device, wellhead moisture meter and gas density gage.

On the basis of the developments mentioned earlier, in 2007 a radically new technology for humidity content measurement named GDG-2 has been created. Survey technology consists of sampling and relative humidity measurement of a sample. If sample relative humidity is 100 %, it is heated up to its equilibrium state with controlled parameters. Humidity is determined by sorption-capacitive elements according to the preset parameters. Results received are additionally verified by gas mixture and moisture vapors density calculations in specified thermo-baric conditions.

The main feature of this measurement technique is its low cost. Required technologies and equipment are 100% manufactured in Russia and device cost amounts to USD 50 thousand. This device precisely and efficiently measures humidity content in well production without gas popping. Dimensions and weight of the unit makes it possible to transport it by intrafield roads all year round without destroying tundra soil cover. As a result technogenic impact is significantly lowered in the area of Company’s activity.

5. Conclusions
Developed well gas dynamic survey and control of main fluid parameters on the wellhead provide measurements in automatic mode using telemetry systems. Developed methods eliminate gas popping and gas flaring product emissions and ensure well operation while surveying. Field development quality and integral volume of produced and delivered gas from the developed field may be seriously raised by the high precision of measurements and possibility to carry out them in any time and without any detriment to the consumers.

Renewable energy sources used to power telemetry system operation gives opportunity to exclude construction of special power-supply systems, which substantially reduces technogenic impact on the very vulnerable nature of the Arctic zone in the Far North of the Western Siberia.

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