NEW TECHNOLOGIES OF GAS PRODUCTION
AT THE URENGOI OIL-AND-GAS CONDENSATE COMPLEX

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ABSTRACT

The paper deals with optimization of technologies for field gas treatment of Cenomanian and Valanginian deposits at the late stage of exploitation of the Urengoi oil and gas condensate complex. As applied to the Cenomanian deposits, these are technologies of two-stage gas drying ensuring removal of hydrates from air-cooling units after the first-stage compression boosters. At present, the two-stage gas drying technology, in various modifications, is implemented at three field units for the Cenomanian treatment.

For operating Valanginian gas treatment units at the late stage a technology for joint work of Cenomanian and Valanginian units was developed with a pressure in low-temperature separators (LTS) corresponding to the pressure of the maximal concentration of hydrocarbons \( C_3^+ \). The use of the modified technology of low-temperature separation of the Valanginian gas results in enhancing the work of the system “reservoir – well clusters – gas collection system – LTS unit”, contributes to the yield of hydrocarbon condensate and efficient use of the existing booster complex capacity. Within the framework of this technology new variants of methanol recirculation with automatic regulation of its consumption were worked out.
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NEW TECHNOLOGIES OF GAS PRODUCTION
AT THE URENGOI OIL-AND-GAS CONDENSATE COMPLEX

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1 INTRODUCTION

Located in West Siberia major world Urengoi gas condensate field is multi-layer object of complicated structure. There are determined productive oil and gas bearing horizons in geological sections from Cenomanian to Jurassic. The history of discovery and development of this field and its satellites is shown on table 1.

At present at Urengoi oil and gas complex under operation are:
- Cenomanian purely gas deposits; in operation are 16 site units of complex gas preparation;
- Gas condensate Neocomian (Valangin) deposits, in operation are 5 site units of complex gas preparation and the latest unit was committed recently (in 2004);
- Oil rims of Valangin deposits (since 1989), in operation are two oil sites;
- Gas condensate Achimovian deposits (in stage of designing and experimental operation).

Urengoi gas condensate field (Cenomanian and Valangin deposits) entered the stage of late development. At present have arisen several technological problems relating to operation of wells clusters, systems of site collection and preparation of gas and HC condensate. To approach these problems underway is complex reconstruction of gas site facilities, refurbishing of main technological equipment and under consideration are the issues of optimization of gas site separation technologies. This paper covers new technical solutions principally capable of providing efficient operation of Urengoi gas condensate complex for the overall coming service life.

Table 1 - History of discovery and development of Urengoi oil, gas, condensate complex in West Siberia

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>Discovery of Urengoi oil, gas, condensate field</td>
</tr>
<tr>
<td>1973</td>
<td>Commencement of construction of operational gas wells</td>
</tr>
<tr>
<td>1978</td>
<td>Foundation of gas producing facility (nowadays-limited liability society “Urengoigazprom”)</td>
</tr>
<tr>
<td>1978</td>
<td>Committed is the first complex preparation unit of Cenomanian productive horizon natural gas from Urengoi field</td>
</tr>
<tr>
<td>1985</td>
<td>Committed is the first complex preparation unit of Neocomian productive horizon natural gas</td>
</tr>
<tr>
<td>1986</td>
<td>Urengoi gas producing complex reached design productivity</td>
</tr>
<tr>
<td>1987</td>
<td>Start of oil production from oil rims of Neocomian productive horizon</td>
</tr>
<tr>
<td>1998</td>
<td>Discovery of North-Samburg field</td>
</tr>
<tr>
<td>2000</td>
<td>Discovery of South-Pestsov field</td>
</tr>
<tr>
<td>2002</td>
<td>From the start of Urengoi complex development was produced and dispatched to the consumer 5 trillion of standard cubic meters on natural gas</td>
</tr>
<tr>
<td>2003</td>
<td>Start of development Tab-Yakhin area (Cenomanian deposit) of Urengoi field</td>
</tr>
<tr>
<td>2003</td>
<td>Start of En-Yakhin field development (Valangin deposit)</td>
</tr>
<tr>
<td>2004</td>
<td>Start of Pestsov field development (Cenomanian deposit) with design productivity 27.5 bn standard cubic meters of gas per year</td>
</tr>
</tbody>
</table>
Main gas reserves were discovered in CENOMANIAN PRODUCTIVE HORIZON

2 TECHNOLOGICAL PROBLEMS OF GAS SITE PREPARATION FOR CENOMANIAN DEPOSITS AND METHODS OF SOLVING THE PROBLEMS

Cenomanian gas deposits – main objects of development at Urengoi complex (see fig. 1, showing the structure of Cenomanian deposits reserves of Urengoi complex). Natural gas of Cenomanian deposits in terms of composition is practically pure methane (with small amount of ethane and propane), its site preparation is done in site conditions at the units of gas complex preparation (UGCP). At UGCP of Cenomanian deposit of Urengoi complex is done initial gas separation, then absorption gas drying, as absorbent is used diethylene glycol (DEG). Thus is reduced moisture content of processed gas and is provided dew point temperature of dried gas in compliance with requirements of Russian standard. Parameters of gas quality per this standard as applied to the north fields of Russia are as follows: gas dew point on humidity (driven to 4 MPa) equals to minus 20 °C in winter season and minus 10 °C in warm season. Technological scheme and detailed description of technological process of Cenomanian productive horizon natural gas preparation is shown in [1].

Due to formation pressure drop, technology of gas drying is complemented with gas compression after the stage of gas drying (after absorber). At further reduction of formation pressure added is one more stage of compression (with putting into operation of booster compressor station (BCS) and gas cooling in air-cooling unit (ACU)). This stage of gas compression is located between the block of gas initial separation and absorber. Thus technology of Cenomanian deposits gas preparation is done at present under the scheme: “gas separation - gas compression (BCS-1) - gas cooling in air cooling units (ACU-1) - absorption gas drying - gas compression (BCS-2) - gas cooling in air cooling units (ACU-2) with further gas delivery to the consumer by trunk pipelines systems.

In the framework of the mentioned technology the problem rose to provide parameters of gas drying in compliance with requirements of industrial standard both for summer time due to growth of contact temperature “gas - absorbent” up to plus 30-35 °C (air cooling unit ACU-1 in summer time is unable to operate because of lack of temperature difference), and in winter time
due to the fact that air cooling unit (ICU-1) will be subject to hydrate thermo-baric conditions (it
does not allow to duly cool gas). Thus at the late stage of Cenomanian deposits development
thermo-baric conditions in absorbers significantly worsened in terms of gas drying efficiency.
To solve the problem of meeting the quality parameters of commercial gas in the view of
further reduction of formation pressure, several technical approaches were developed:
• Increase in mass exchange efficiency in absorbers (substitution of mass exchange part in units
by regular packing providing mass exchange efficiency at the level of 2nd theoretical trays, see
detailed discussion in [2]),
• Improving design of ACU units for non-dried gas and development of automation management
systems,
• Options for modification of gas absorption drying technological schemes not demanding
refurbishing technological trains (introduction of the preliminary stage of drying at one of the
technological trains with the use of saturated DEG solution at the preliminary stage of drying,
remanolofolding of two technological lines into one with movement of gas steam to be dried,
subsequently through 2 absorbers, dried gas stream recirculation with the use of ejector etc.),
• Options of UGCP upgrading at the last stage of Cenomanian deposits operation (transfer of
some of the units into the mode of units for preliminary gas drying with further final drying in the
major UGCP).
Below you will find discussion on some of implemented technical approaches at
Cenomanian UGCP.
Technological schemes of two-stage gas drying implemented at one technological train

The first stage of drying is done after the stage of initial gas separation (gas purification
shop) by injection through sprayer the saturated DEG before filter-separator. At the first stage
dering of raw gas occurs in favorable temperature mode (contact temperature in absorber is
\( \sim 10^oC \)), due to which at the preliminary stage of drying from gas is removed approximately the half
of water steam contained there. The second stage of drying is done as per the usual scheme in
absorbers. As absorber at the second stage is used regenerated DEG solution arriving from DEG
regeneration unit. In absorbers regenerated DEG by contacting with gas at mass exchange units
absorbs moisture remaining in gas after the first (preliminary) stage of drying. This technology
provides for gas drying efficiency for certain time period after switching on booster compressor
station before absorber.

Technological schemes of two-stage absorption drying at the late stage of Cenomanian
deposits

One of the most optimal options for Cenomanian UGCP is two-stage gas drying with
reduction of technological trains quantity at the unit (at the late stage of operation it is possible due
to decreasing of natural gas compression unit productivity at formation pressure drop in the
deposit). The essence of technology is treatment of gas steam subsequently trough two
technological trains and gas passes successively through two absorbers. At present such
technology is implemented at several units of gas drying. In the considered scenario the process
diagram can be described in such a way: «Inlet separator – Absorber-1 – BCS-1 – ACU-1 – BCS-2
– ACU-2 – Absorber-2». As per the results of the fulfilled calculations of the considered technology
it is stated that above said absorber upgrading (i.e. substitution of the mass exchange part of
absorber for regular packing) is feasible to implement only for the second (final) absorber. Thus is
facilitated the operation of ACU-1, the first in the direction of gas movement. And the second
absorber operates in favorable thermo-baric conditions. Application of this technological scheme of
gas preparation allows to guarantee with the necessary technological gap the required quality of
gas preparation for the whole period of gas preparation (until 2020). Besides, this technology
allows to drive the specific technological losses of absorbent (DEG) to technological minimum (up
to \( \sim 1-2 g/1000 m^3 \)).

Another alternative to optimization of the gas dehydration parameters may be the use of
the technology with gas being dehydrated passing through two complex gas-conditioning units
(CGCU). This technology was developed for the final development stage of the Urengoi complex
Cenomanian deposits (for the period after 2020). At this stage of the Urengoi field development
three units (three CGCU) may be used as gas pre-dehydration units under the existing (designed) scheme due to lowering load on the basic dehydration equipment. Further the partially dehydrated gas enters the fourth unit to undergo final drying. The conducted process calculations demonstrated that by implementing this scheme the required gas quality indices may be achieved all along through the end of the development. It should be emphasized, however, that implementation of this engineering option necessitates certain capital expenditures.

**Automatic control system for a raw gas air cooler**

In air coolers (AC), the raw (not dried) gas passes through rows of heat exchange tubes, which are aired by cool flows (in winter, temperatures minus 20 to minus 50 °C). In this case, gas in different heat exchange tubes (AC sections) is cooled strongly non-uniformly along the air flow and, consequently, hydrate sediments are likely to occur in small-diameter tubes (which may fail). Use of hydrate inhibitor (methanol) is undesirable, as it leads to considerable deterioration of the gas dehydration indices. Performance of the AC gas is improved significantly if a process flow sheet with gas pre-dehydration stage is used, but this requires development of the AC operation automation system.

The AC automation system is designed to hold the optimum gas outlet temperature in air coolers and to prevent gas hydrate formation in heat exchange tubes. Depending on the temperature sensor indications, a change in the rotating speed of the running fans holds the temperature at the AC outlet gathering sections. The senses are mounted in thermo-pockets on the air cooler outlet gathering lines. At the same time the system automatically controls the state of the first (downstream air flow) rows of tubes, preventing formation of solid hydrate blocks. An attached temperature sense fitted on the most cooled AC lower tube controls the state of the tubes. If the tube section is almost completely blocked with hydrate, the gas temperature in the pipe drops to the outside temperature, and it serves as a signal to switch on the low-speed fan reversing gear (after a brief warming-up stop). The fan reversing gear makes it possible to quickly warm up the lower rows of tubes preventing, at the same time, rise in gas temperature at the outlet gas gathering lines.

In this manner, the above-said complex technology allows solving the gas treatment problems at the late and final development stages of the Urengoi field Cenomanian deposits, i.e. ensures an efficient and reliable operation of the field gas-gathering systems and dehydration units over the entire development period with minimal costs of the material and technical resources.

**3 PROCESS PROBLEMS OF VALANGINIAN GAS FIELD TREATMENT AT FINAL STAGE OF THE FIELD DEVELOPMENT AND THE WAYS OF THEIR SOLUTION**

Gas treatment technology that is used at complex gas-conditioning units (CGCU) of the Urengoi field’s Valaginian pool includes low-temperature separation (LTS) method with three separation stages. As designed, separation temperature is 30 °C and pressure is between 7.5 MPa (at initial stage of development) and 5.0 and lower MPa (at final stage of development). Concentrated methanol is used as hydrate inhibitor. Treated gas is fed to a field gathering main pipeline and HC condensate is fed to a stabilization and gas-fractionation plant.

The main problems operators are facing during LTS unit operation at final stage of the Valanginian gas extraction are as follows:

- Decrease in heavy HC extraction from formation gas due to a rise in separation temperature as CGCU input gas pressure decreases;
- Increase in HC drop-like condensate loses with separator gas due to increasing a gas velocity factor in LTS units;
- Change of thermo-baric parameters in gas gathering systems with shifting them into a hydrate formation zone and, as a result, the increase of methanol consumption which is needed to prevent hydrate formation in the above systems.
To solve the above-mentioned problems the following complex of measures is suggested:

- Modification of gas conditioning flow charts;
- Modification of hydrate inhibitor recirculation technologies (methanol at LTS units);
- Improvement of separation equipment (separators of a final stage of gas separation).

To select design options of conditioning gas at late stage of Valanginian CGCU operation calculation and experimental investigations have been carried out on one of the gas-conditioning units for determining pressure of heavy HC maximum condensation. Fig. 2 illustrates a change in heavy HC content in separator gas (sales gas).

**Figure 2.** Change in C₅₊ and C₃₊HC content in separator gas on CGCU-2B vs. separation pressure (at separation temperature minus 30 °C)

**Figure 3.** Combined operation of Valanginian CGCU with using booster power of Cenomanian CGCU
It is seen from Fig. 2 that optimal separation pressure amounts to 4 to 5 MPa. The data obtained have allowed developing flow charts for combined operation of Cenomanian and Valanginian gas-conditioning units, Fig. 3. At that, Valanginian gas separation temperature is kept at −30 °C during the whole period of the units operation. In order to maintain pressure in LTS at an optimal level of 4-5 MPa NTS technology is to be modified in a certain way. For this purpose a method of throttling gas in two stages upstream and downstream of LTS has been developed.

At present, the design options suggested are applied in different variants at four Valanginian CGCU units. Operation experiments have shown that the use of Cenomanian boosters for compressing Valanginian CGCU gas allows solving the problem of separation temperature rise that takes place in design technology. The field tests have shown that the application of the combined operation Valanginian and Cenomanian pools and gas throttling on field gas pipeline in two stages will enable to postpone commissioning of Valanginian CGCU units by 4-5 years up to gas inlet pressures of 5-5.5 MPa. For operating CGCU in this period a Valanginian booster-CGCU-Cenomanian booster process chart has been developed, Fig. 4.

Figure 4. Process chart of Valanginian CGCU operation after putting a booster into service before CGCU
As it was stated before, methanol is used as hydrate inhibitor in LTS units. Presently, the technologies of optimal methanol application with recirculation of water-methanol solutions (WMS) and methanol regeneration from solutions in gas flow itself have been realized, Fig. 5. As for a late stage of Valanginian CGCU operation (according to the process chart of Fig. 4), variants of recirculation of water-methanol flows that take into account high temperature of gas leaving the Valanginian booster (over 50 °C) locating at the head of the process. The necessity on a gradual increase in supplying methanol into the field gathering system (to gas condensate well clusters) with the realization of a system of methanol distribution by the well clusters.

**Figure 5. Operating technology of methanol recirculation on the Valanginian LTS unit**

CR – control room; S-1 – inlet separator; SD – desorber-separator; H-1, H-2 – heat exchangers; S-2 - intermediate separator; S-3 – low temperature separator (outlet separator); P-1, P-2, P-3 – pumps; BV – buffer vessel; D-1, D-2, D-3 – three phase divider-separator.

### 4 CONCLUSIONS

Upgraded technologies for conditioning Valanginian and Cenomanian gas on the Urengoi field as applied to late and final stages of the field development are suggested.

Two-stage gas dehydration technology that ensures hydrate-free air cooler operation downstream of the 1st compression stage booster (two-stage gas dehydration on two thermo-baric levels) has been applied on the Cenomanian gas-conditioning units. At present, different modifications of this technology is used on three Cenomanian gas-conditioning units.

As applied to the Valanginian CGCUs, the technology of combined operation of Cenomanian and Valanginian CGCUs that makes it possible to maintain gas pressure in LTS units at a level of 4.0-4.5 MPa (pressure of maximum C3+ condensation) has been developed. This technology improves the operation of a “reservoir-well cluster-gas gathering system-LTS unit”
system and increases a HC condensate output and the opportunities of low-pressure degassing gas utilization. In this case the booster power of the Cenomanian CGCUs is used. In the framework of the technology offered LTS units have been additionally upgraded for their operation under decreased pressures and thus reduction of aerosol losses of HC condensate with separator gas. Besides, new design options for recirculation of methanol used as hydrate inhibitor with automatic control of its consumption have been developed for the same technology.

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