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## **Determination and Application of Polypropylene Glycol Consumption Norm in the Gas Dehydration Facility**

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### **Abstract**

The article presents the development and industrial implementation of a new hydrate formation inhibitor based on domestic petrochemical products as an alternative to methanol. The inhibitor was created on the basis of extensive theoretical and experimental research and introduced into the gas preparation system for the first time. The introduction of the new reagent ensured effective prevention of hydrate formation during gas production, treatment, and transportation. The developed inhibitor demonstrated high efficiency in field gas processing and provided stable operation of gas treatment facilities under various thermodynamic conditions. Industrial application of the proposed inhibitor at major oil and gas production facilities of the republic confirmed its technological reliability, economic efficiency, and environmental safety. The results show that replacing traditional methanol with the newly developed reagent contributes to improved gas processing quality, prevention of technological complications, and reduction of operating costs.

**Keywords:** gas industry, gas drying, methanol, inhibitor, hydro formation.

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## **Qaz qurutma qurğularında polipropilenqlikolun istifadəsi və sərf normasının təyini**

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### **Xülasə**

Məqalədə çoxsaylı nəzəri və eksperimental tədqiqatlar əsasında ölkəmizin neft-kimya məhsulları bazasında metanolun əvəzinə yeni hidrat əmələgəlmə inhibitorunun işlənilib hazırlanması və sənaye tətbiqi tədqiq edilib. Hazırlanmış inhibitor qazın hasilatı, emalı və nəqlə hazırlanması prosesində hidrat əmələgəlməsinin effektiv qarşısını almağa imkan vermişdir. Yeni reagent müxtəlif termodinamik şəraitlərdə qaz emalı qurğularının sabit və etibarlı işləməsinə təmin etmişdir. Təklif olunan inhibitorun neft-qaz sənayesi obyektlərində tətbiqi onun texnoloji cəhətdən səmərəli, iqtisadi baxımdan məqsədəuyğun və ekoloji təhlükəsiz olduğunu göstərmişdir. Metanolun yeni reagentlə əvəz olunması qazın emal keyfiyyətinin yüksəldilməsinə, texnoloji pozuntuların azaldılmasına və istismar xərclərinin aşağı salınmasına şərait yaratmışdır.

**Acar sözlər:** qaz sənayesi, qazların qurudulması, metanol, inhibitor, hidratəmələgəlmə.

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## **Использование и определение нормы расхода полипропиленгликоля на установке осушки газа**

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### **Аннотация**

В статье на основе многочисленных теоретических и экспериментальных исследований разработан и внедрён новый ингибитор гидратообразования на базе отечественных нефтехимических продуктов взамен метанола. Применение разработанного реагента обеспечило эффективное предотвращение образования гидратов в процессе добычи, подготовки и транспортировки газа. Новый ингибитор подтвердил свою высокую эффективность и надёжность работы газоподготовительных установок при различных термодинамических условиях. Промышленное внедрение предложенного реагента на объектах нефтегазовой отрасли республики показало его технологическую эффективность, экономическую целесообразность и экологическую безопасность. Замена метанола новым ингибитором способствует повышению качества подготовки газа, снижению технологических осложнений и уменьшению эксплуатационных затрат.

**Ключевые слова:** газовая промышленность, осушка газа, метанол, ингибитор, гидратообразования.

## **Introduction**

At the present stage of development, gas is considered one of the most efficient and economical types of fuel. The products of gas and gas condensate fields represent complex raw materials for various industries. The development of the gas industry is characterized by an integrated approach to the utilization of extracted hydrocarbon resources. Gas and gas condensate deposits of the southern fields are potentially important suppliers of commercial gas. Currently, all extracted gas is processed at field gas treatment plants to produce commercial-grade gas and ensure proper transportation conditions.

Due to the fact that natural gas is transported over long distances from production sites to consumers through gas pipelines crossing various climatic zones, the issue of its high-quality processing and drying to the dew point, eliminating the condensation of water from the gas, is of particular importance.

An urgent task in preparing natural gas for transportation is a high-quality process of extracting moisture from gas using an effective liquid absorbent inhibitor of hydrate formation. To prevent hydrate formation in field conditions, the article considers the possibility of using an economically advantageous and environmentally friendly absorbent - polypropylene glycol (PPG), developed on the basis of domestic petrochemical products, which ensures the extraction of condensed moisture from gas (at the level of the dew point temperature for water  $-5-10^{\circ}\text{C}$ ).

## **Statement of the problem**

During gas production in industrial processing flow charts, thermodynamic conditions (pressure, temperature) change, under which moisture vapor condenses. The precipitated

condensed moisture causes complications both in the technological elements of industrial gas treatment units and during its transportation through main gas pipelines. Moisture, interacting with gas under certain thermodynamic conditions, forms solid crystalline substances – hydrates. The main complication is the formation of hydrate plugs.

The presence of moisture, liquid hydrocarbons, aggressive and mechanical impurities in gas reduces the through put of gas pipelines, increases the consumption of inhibitors, increases corrosion, increases the required power of compressor units, and contributes to clogging of control and measuring instrument lines.

All this reduces the reliability of technological systems, increases the likelihood of emergency situations at compressor stations and gas pipelines.

Therefore, before feeding natural gas into main gas pipelines, the gas is processed to a certain condition, i.e. a separation and drying system is provided.

Hydrocarbon gas drying is an important link in the process of preparing natural gases for transportation through main gas pipelines. The choice of drying method depends on specific conditions and requirements, namely: gas composition, required drying depth, volume of gas to be dried, etc.

In world practice, to prevent hydrate formation in field conditions, the method of feeding an inhibitor into the gas flow is widely used, and then the gas is dried using glycols – polyhydric alcohols [1-4].

At present, methyl alcohol is used as a hydrate formation inhibitor and DEG (diethylene glycol) as a dehydrator for gas preparation at gas condensate and gas fields. Other liquid absorbents have not found wide application.

## **Analysis of the latest research on the topic of the article**

With the intensive development of the gas industry and taking into account the commissioning of new gas and gas condensate fields in the Caspian Sea region, it is necessary to develop and implement new technological processes, as well as improve existing technology and equipment using an effective absorbent for high-quality processing of natural gas. For this purpose, tests were carried out using an effective and environmentally friendly hydrate inhibitor PPG in industrial conditions as a gas dehydrator [5-7].

The tests were carried out on an industrial unit operating at the Sand Island NGDU enterprise. The process flow chart of the industrial gas drying unit is shown in Fig. 1.

The unit's capacity on gas was 1.1 million m<sup>3</sup> of gas/day. 22 tons of the new absorbent were used to conduct pilot tests on the unit. According to the flow chart, gas from the compressor station under a pressure of 7.0 and 6.9 MPa with a temperature of 35-45°C enters the first-stage separator (C-1), where rough separation of gas from liquid droplets and mechanical impurities occurs. Then the gas enters the second-stage separator (C-2), where additional separation of gas from liquid occurs. Then the gas enters the absorber, where final gas drying takes place. To dry the gas, polypropylene glycol inhibitor is injected into the absorber at four points under a pressure of 8.5 MPa. After contact with the gas, the moisture-saturated PPG is collected in a container, from where it is fed to the regeneration unit (RU) using a pump, and then the regenerated absorbent is fed back into the absorber and the process is repeated in a closed circuit. The dried gas enters the third-stage separator expander (G-3), and then under a pressure of 6.9-6.8 MPa is sent to the gas col-

lector and then to its intended purpose. During the test, the following parameters were determined: pressure, drying process temperature, plant capacity for dried gas, regeneration temperature, amount of absorbent injected into the gas flow, concentration of regenerated and moisture-saturated absorbent, etc. [8,9].

As the results of multiple use of PPG in the field gas treatment system showed, no technological deviations in the operation of the unit were observed during the testing period. Based on the results of the studies, the optimal technological mode of operation of the gas drying unit using the absorbent polypropylene glycol was selected:

Concentration of regenerated.

Polypropylene glycol, % mass -97,5-98,5.

Concentration of saturated.

Polypropylene glycol, % mass -93,0-95,0.

Temperature of regeneration saturated polypropylene glycol, °C.

In winter season -145-155.

In summer season -141-145.

Gas-absorbent contact temperature, 33-46°C.

Polypropylene glycol density, kg/m<sup>3</sup> - 1030-1033.

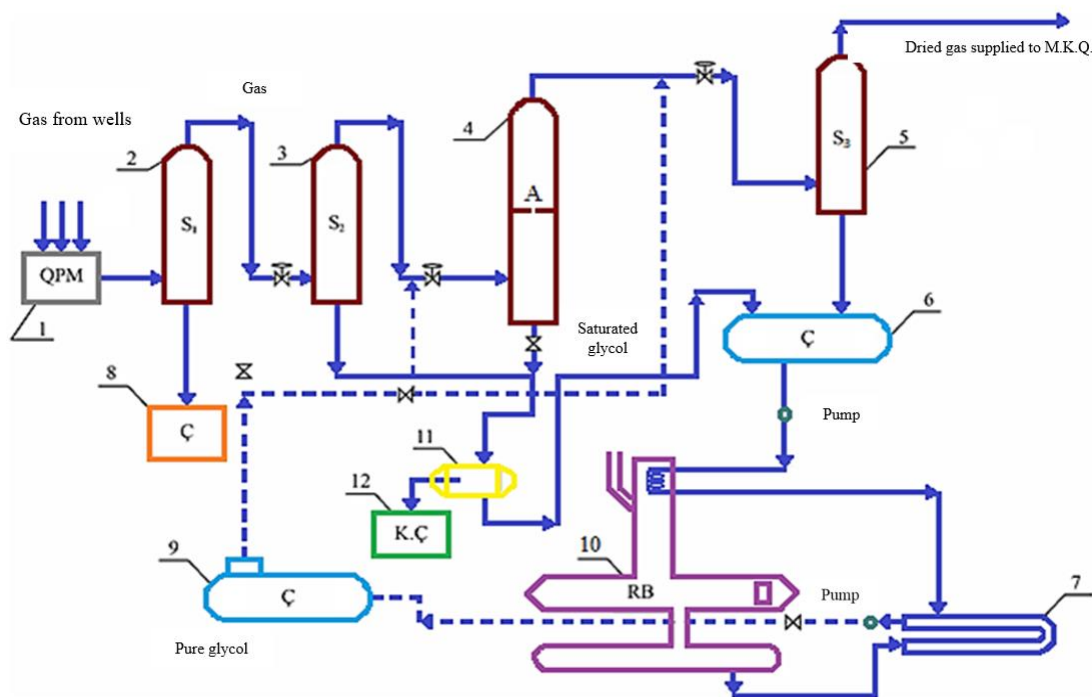
Specific polypropylene glycol feed into the gas flow, kg/1000 m<sup>3</sup> gas -11-13.

Dew point of dried gas, °C minus 5-10

Total absorbent losses in the system, g/1000 m<sup>3</sup> gas -95-115.

It is evident from the table that the selected process mode achieves the required dew point of the dried gas and ensures the quality of the gas prepared for transport.

The results of the pilot industrial tests also showed that polypropylene glycol is an economical, effective, environmentally friendly absorbent and does not create difficulties in the technology of gas drying installation.



**Figure 1** – Technological scheme of an industrial plant for drying gas.

1 - gas from the well; 2,3 - separators; 4-absorber; 5 - filter; 6 - capacity for saturated absorbent;  
 7 - heat exchanger; 8 - capacity for liquid; 9 - capacity for absorbent; 10 -regeneration unit;  
 11-separator; 12-condensate tank.

**Table 1** – Glycol losses at a field gas drying plant

Nature of Glycol Losses	% loss	Measures to reduce losses
Mechanical Carryover with Gas Flow	71,5	Reducing the speed of separation gas
Losses Due to Evaporation	7,2	Sealing glycol tanks
Losses with Water	8,0	Carrying out glycol regeneration
Losses with Hydrocarbon Condensate	8,5	Separating glycol from condensate by settling
Losses from Thermal	1,1	Reducing the temperature of glycol regeneration or using vacuum regeneration

Based on the positive test results, polypropylene glycol as a new absorbent for gas drying is recommended for widespread implementation at the oil and gas production facilities of the Azneft Production Association.

**Identification of a part of the unresolved problem.** Based on the above, an analysis of studies to determine the losses of the

PPG absorbent at a field gas drying plant was also conducted. The results obtained are presented in table 1.

It is evident from the table that the largest share of glycol losses is due to mechanical carryover with the gas flow from the absorber, as well as from the separator. Therefore, during separation, it is recommended to maintain

the gas velocity of no more than 0.2 m/sec, since with an increase in the gas velocity, the carryover of glycol also increases.

Heating can be used for the same purposes in conditions where hydrates are formed as a result of local gas reduction, and the operating temperature in the gas pipeline exceeds the equilibrium temperature of hydrate formation.

It should be noted that under conditions of possible hydrate formation without gas heating, not only standard control valves but also pressure regulators operate unsatisfactorily. Gas heating is not an effective method of combating moisture freezing in pipes and hydrate formation, since the gas relatively quickly acquires the temperature of the environment.

The pressure reduction method is used both to eliminate already formed hydrates and to prevent their formation. In the first case, a sharp decrease in pressure leads to the decomposition of hydrates, which requires a certain period of time: from several minutes to several hours, depending on the soil temperature and the nature of the plug.

This method is effective in eliminating hydrate plugs formed at positive temperatures and is unsuitable at soil temperatures below 0 °C, since when hydrates decompose, water turns into ice and an ice plug is formed.

The pressure reduction method can be used in emergency situations to decompose hydrates in a gas pipeline by briefly reducing the pressure below the hydrate decomposition pressure.

Studies of the efficiency of multi-stage gas throttling to combat hydrate formation have shown that if the liquid phase is separated after each nozzle in a multi-stage manner, this produces a great effect.

When it is impossible or impractical to use the first two methods, hydrate formation inhibitors are introduced into the gas flow. They partially absorb water vapor and transfer it together with free water into solution. The latter either does not form hydrates at all or forms them at temperatures lower than the hydrate formation temperature in the presence of pure water.

Based on the above, when designing glycol drying units, in order to increase the cost-effectiveness of the process, it is necessary to provide glycol collection filters after the absorber.

### **Formulate the purpose of the research**

To ensure uninterrupted gas transportation, it is necessary to improve the gas preparation technology. For this purpose, it is necessary to study the gas preparation technology and calculate the absolute rate of inhibitor consumption.

In order to reduce operating costs for preventing hydrate formation in the gas production and transportation preparation system, the following measures must be taken.

- improvement of the methodological basis for calculating the consumption rate of inhibitors used in gas preparation technology;
- analysis of the reasons for significant deviations in a number of cases of the actual consumption of inhibitor from the calculated one;
- development of automatic flow control systems and devices for the removal of anti-hydrate inhibitors into the gas flow, etc.

In recent years, the methodology for calculating the consumption rates of hydrate formation inhibitors has been improved.

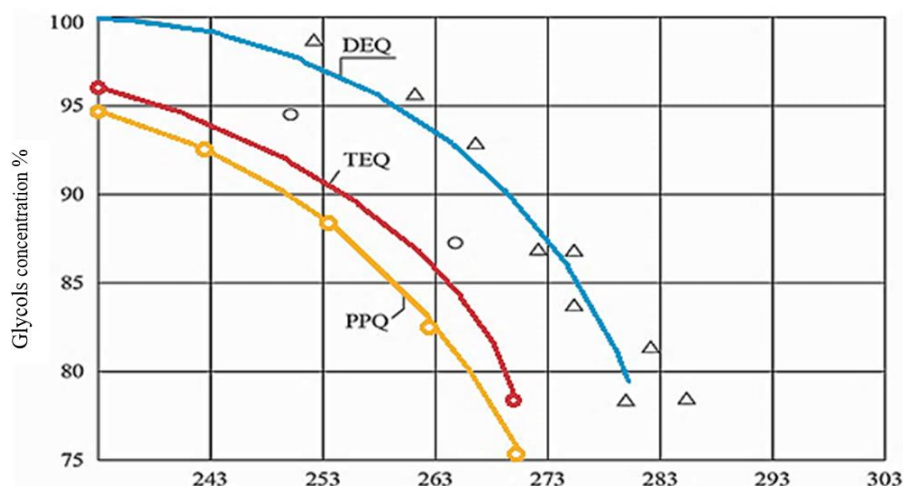
It has been established that aqueous solutions of polypropylene glycol have good

anti-hydrate properties, on the basis of which it is proposed to use it, along with traditional reagents (diethylene glycol and triethylene glycol) to prevent hydrate formation in the system of production and field preparation of natural gas for transportation. Figure 2. The preliminary consumption rate of the absorbent as an inhibitor for preventing hydrate formation has been determined by calculation.

During the research, the degree of regen-

eration of complex polypropylene glycol saturated with water vapor was studied and it was established that at a temperature of 140 ... 1500 C, the concentration of the regenerated absorbent reaches 98.5 ... 99.0% by weight.

Based on the results of the conducted studies, it was established that the developed polypropylene glycol based on domestic petrochemical products is an effective, environmentally friendly reagent.



**Figure 2** – Dependence of the dew point of dried gas on the concentration of glycols and contact temperature.

1-diethylene glycol; 2-polypropyl eneglycol; 3-triethylene glycol.

It is known that during seasonal gas extraction from underground storage facilities, the thermodynamic parameters of the gas, namely, pressure, temperature and flow rate, do not change in the shortest possible time, due to which the yield of formation mineralized water also increases. This, in turn, significantly affects the degree of gas drying.

Therefore, ensuring the required dew point of the gas dried from moisture according to the requirements of the industry standard, until the end of the extraction, depends on the correct choice of the optimal parameters of the absorbent and the absorption gas drying unit.

Based on the results of the conducted research for gas preparation, the following technological parameters of the gas and polypropylene glycol drying unit were selected.

- Unit capacity by gas, million, mln m<sup>3</sup> .....6-19
- Gas pressure at the absorber inlet, MPa .....4,0-7,5
- Gas temperature at the absorber inlet, °C .....10-14
- Absorbent concentration, % by weight:
  - saturated ..... 93-98
  - regenerated ..... 99-99,5
- Saturated glycol regeneration
  - temperature, °C .....140 -145
- Dried gas dew points by moisture, °C ... minus 10-20
- Complex absorbent density, kg/m<sup>3</sup> ..... 1030-1033
- Specific absorbent feed for gas drying,
  - kg/1000 m<sup>3</sup> .....20,0...25,0

Thus, it should be noted that with the implementation of this development in the system and field preparation of gas during seasonal extraction, the following indicators can be achieved:

- The dew point of the gas dried from moisture will meet all the requirements of the industry standard;

- gas loss due to the formation of hydrates in the system will be excluded;

- the liquid phase will be prevented from entering the main gas pipeline, as a result of which the technological mode of operation of the transportation network will be stabilized;

- the costs of transporting gas to the consumer will be significantly reduced;

- the use of polypropylene glycol based on domestic petrochemical products to prepare gas for transportation will eliminate the purchase of imported chemical reagents.

To calculate the consumption rate of polypropylene glycol used for gas drying, the actual process parameters of the gas drying unit operated at N. Narimanov NGDU and Sand Island were used

Taking into account the climatic condi-

tions of the region, according to the standards, the dew point temperature of the dried gas should be minus 5°C. In order to obtain the specified dew point temperature of the dried gas at a pressure of 6.5-7.0 MPa and a temperature of 20-25°C, it is necessary to determine the required gas dew point depending on the concentration of glycol that will be used in the gas drying unit.

The results of the preliminary studies are presented in Table 2.

Using the formula below, we determine the total content of moisture absorbed by the absorbent from the gas. [10-11]

$$W = Q_{\text{gas}} (W_1 - W_2)$$

W- total moisture content extracted from gas, kg/1000 m<sup>3</sup>

W<sub>1</sub>- initial moisture content of the feed gas;

W<sub>2</sub>- moisture content of dry gas

Q<sub>gas</sub> - amount of gas from the well per hour/m<sup>3</sup>

Using the values of actual technological indicators, which are given in Table 3, we continue the calculation

$$W = 50000(0,64 - 0,08) = 28 \text{ kg/hour}$$

**Table 2** – Dependence of the dew point temperature of the dried gas on the concentration of polypropylene glycol

Dew point temperature of dry gas. °C	0	-5	-10	-15	-20
Polypropylene glycol concentration	92,0	93,0	95,0	96,0	97,0

To achieve a dew point of dried gas of minus 5°C, the consumption rate of polypropylene glycol supplied to the gas flow is calculated.

To determine the consumption rate of polypropylene glycol, the following preliminary indicators of the gas drying plant using polypropylene glycol are used:

- concentration of fresh PPG, % mass - 98,0;

- concentration of saturated PPG, % mass. - 96

- gas plant capacity, thousand m<sup>3</sup>/hour - 50000

- the amount of moisture extracted from the gas, kg/hour - 28

To perform the calculation, all technological parameters are known and then we determine the consumption rate of polypropylene glycol.

The consumption rate of polypropylene glycol is determined by the formula

$$C = \frac{W \cdot x_2}{x_1 - x_2}$$

C - total consumption of polypropylene glycol supplied to the gas flow,

W - amount of moisture extracted from the gas,

X<sub>1</sub> - concentration of fresh polypropylene glycol

X<sub>2</sub> - concentration of saturated polypropylene glycol

Thus, to dry 1000 m<sup>3</sup> of gas to the required condition, the polypropylene glycol consumption rate supplied to the gas flow should be 13.40 kg. It should be noted that when changing the thermodynamic and technological parameters of the gas drying unit, as well as the dew point temperature of the dried gas, the polypropylene glycol consumption rates can change significantly.

If the gas from the well comes under high pressure, a low temperature can be achieved by throttling the gas; this ensures self-cooling. In some units, where the gas is supplied under low pressure, low temperatures are achieved by ammonia or propane cooling. In both types of units, it is necessary to cool the gas below the hydrate formation temperature to ensure effective capture of hydrocarbons capable of passing into a liquid state. The low temperature to which the gas is exposed usually guarantees sufficient dehydration of the outgoing gas stream for its transportation without further drying. Additional temperature reduction by 5,6 °C under normal operating conditions the unit provides an additional cap-

ture of approximately 2.9 g of condensate per 1 m<sup>3</sup> of gas. Simple expansion cooling systems without inhibitor can typically be used to produce 0.10-0.12 kg of condensate per 1000 m<sup>3</sup> of gas at a pressure drop of about 80-82 kg/cm<sup>2</sup>. More efficient condensate collection and dehydration is achieved by using a hydrate inhibitor and by using cold gas at the outlet of the low-temperature separator to pre-cool the incoming gas below the hydrate formation temperature, which ensures a lower temperature in the separator.

As the well pressure decreases and the pressure drop approaches 68 kg/cm<sup>2</sup>, a hydrate inhibitor is required to obtain 0.113 kg of condensate per 1000 m<sup>3</sup> of gas.

The cost of glycols is significantly reduced by their regeneration. The choice of glycol depends on the freezing point of aqueous solutions, viscosity, decrease in the hydrate formation temperature for a given concentration, glycol solubility in the hydrocarbon phase, vapor pressure, temperature of the liquid and gaseous phases in the low-temperature separator, and the gas-condensate ratio.

Analysis of the results of industrial implementation and technical and economic indicators of polypropylene glycol in the preparation of natural gas for transportation at offshore oil and gas fields in the region over a long period of operation showed that due to changes in the parameters of the extracted products, it is necessary to systematically monitor industrial implementation in order to promptly eliminate technological deviations in the system. In addition, it is necessary to regularly calculate the norms of reagent consumption depending on changes in thermodynamic, technological and other indicators in the system of gas production, collection and preparation for transportation.

## Conclusions

Many years of experience in the operation of integrated gas treatment plants has shown that poor gas processing at the fields occurs due to modern technological processes, as well as effective gas dryers inhibitors to prevent technological deviations in the system of production and field gas treatment.

Based on numerous theoretical and experimental studies, a new hydrate formation inhibitor based on domestic petrochemical products has been developed and introduced for the first time to replace methanol. The in-

roduction of a new inhibitor has made it possible to ensure effective prevention of hydrate formation in the system.

The use of a new inhibitor, compared to methanol, allows to reduce the cost of the processed gas, which ensures the extraction of moisture from the gas and improve the operation of integrated gas treatment plants.

## Conflict of Interests

The authors declare there is no conflict of interests related to the publication of this article

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