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The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.

The journal is also included in the Emerging Sources Citation Index (ESCI) of the Web of Science platform (Clarivate Analytics, since 2018).

Indexing in ESCI confirms the journal's compliance with international standards of scientific peer review and editorial ethics and is considered by Clarivate Analytics as part of the evaluation process for potential inclusion in the Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI).

Indexing in Scopus and Web of Science ensures high international visibility of publications, promotes citation growth, and reflects the editorial board's commitment to publishing relevant, original, and scientifically significant research in the fields of geology and technical sciences.

«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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OPTIMIZATION OF THE CLAUS PROCESS TO INCREASE THE YIELD OF ELEMENTARY SULFUR FROM HYDROGEN SULFIDE AND SULFUR DIOXIDE

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Abstract. *Relevance.* This solution is aimed at increasing the yield of elemental sulfur and reducing its maximum particle size by controlled reduction of supersaturation in the unit. An engineering methodology is also presented for predicting the particle size distribution of dispersed desublimation products under varying process parameters. *Objective.*The primary objective of this study is to increase the yield of elemental sulfur in a Claus unit cycle. Optimization of the operating modes of the desublimation condenser is proposed as a solution. The primary objective of the study is to identify parameters that maximize the yield of pure sulfur. *Methods.* The key technological step is desublimation condensation: cooling the gas to a temperature below the melting point of sulfur, allowing the vapor to bypass the liquid phase and crystallize directly into a solid. This study developed a new approach to desublimation control. Its algorithm includes two sequential stages. First, the pressure in the initial vapor-gas mixture is gradually reduced at a constant temperature until a critical value is reached. Then, maintaining the pressure constant, the medium is intensively cooled to the dew point temperature. This method enables the production of a narrow-fraction, ultrafine powder, significantly reducing energy costs. The proposed technology is versatile and can be used to produce finely dispersed powders of various substances (in particular, sulfur, silicon, etc.) by desublimation. The effectiveness of this method lies in its ability to stabilize the particle size distribution of the final product, which directly improves its quality characteristics. *Results and Conclusions.* The process of producing ultrafine silicon dioxide powder was chosen as the object of study for the experiments. Particular attention was paid to studying the influence of supersaturation, as well as analyzing the characteristics and kinetics of the process. The paper formulates recommendations for upgrading the Claus process line, including placing a desublimation condenser before the second scrubber stage.

Keywords: desublimation method, Claus process, elemental sulfur, crystallization, finely dispersed powder

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КҮКІРТСУТЕК ПЕН КҮКІРТ ДИОКСИДІНЕН ЭЛЕМЕНТАРЛЫ КҮКІРТТІҢ ШЫҒУЫН АРТТЫРУ ҮШІН КЛАУС ПРОЦЕСІН ОҢТАЙЛАНДЫРУ

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Аннотация. *Өзектілігі.* Бұл шешім аппараттағы шамадан тыс қанығуды бақыланатын түрде азайту есебінен элементар күкірттің шығымын арттыруға және оның бөлшектерінің максималды мөлшерін азайтуға бағытталған. Қосымша, технологиялық параметрлерді өзгерту кезінде десублимацияның дисперсті өнімдерінің фракциялық құрамын болжауға мүмкіндік беретін инженерлік әдістеме ұсынылған. *Әдістері.* Бұл жұмыстың негізгі мақсаты – Клаус қондырғысы циклindeгі элементті күкірттің шығымын арттыру. Шешім ретінде десублимациялық конденсатордың жұмыс режимдерін оңтайландыру ұсынылады. Зерттеудің басты міндеті – таза күкірттің максималды шығымын қамтамасыз ететін параметрлерді табу. *Мақсат.* Негізгі технологиялық тәсіл – десублимациялық конденсация: газды күкірттің балқу температурасынан төмен температураға дейін салқындату, соның арқасында булар сұйық фазаны айналып өтіп, бірден қатты затқа кристалданады. Зерттеу аясында десублимацияны басқарудың жаңа тәсілі әзірленді. Оның алгоритмі екі сатыдан тұрады. Алдымен, бастапқы бу-газ қоспасында тұрақты температурада қысымды сыни көрсеткішке жеткенше біртіндеп төмендетеді. Содан кейін, қысымды өзгеріссіз сақтай отырып, ортаны шық нүктесі температурасына дейін қарқынды салқындатады. Бұл әдіс энергия шығындарын айтарлықтай азайта отырып, тар фракциялы ультрадисперсті ұнтақ алуға мүмкіндік береді. Ұсынылған технология әмбебап болып табылады және десублимация әдісі арқылы әртүрлі заттардың (әсіресе күкірт, кремний және т.б.) ұсақ дисперсті ұнтақтарын алу үшін қолданылуы мүмкін. Әдістің тиімділігі соңғы өнімнің фракциялық құрамын тұрақтандыру мүмкіндігінде жатыр, бұл оның сапалық сипаттамаларын тікелей жақсартады. *Нәтижелер мен қорытындылар.* Эксперименттер барысында кремний диоксидінің ультрадисперсті ұнтағын алу процесі зерттеу нысаны ретінде таңдалды. Шамадан тыс қанығу дәрежесінің әсерін зерттеуге, сондай-ақ процестің сипаттамалары мен кинетикалық заңдылықтарын талдауға ерекше назар аударылды. Жұмыста Клаус технологиялық желісін жаңғырту бойынша ұсыныстар тұжырымдалған, оның ішінде десублимациялық конденсаторды скрубберлердің екінші сатысының алдына орналастыру қарастырылған.

Түйін сөздер: десублимация әдісі, Клаус процесі, элементар күкірт, кристалдану, ұсақ дисперсті ұнтақ

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ОПТИМИЗАЦИЯ ПРОЦЕССА КЛАУСА ДЛЯ УВЕЛИЧЕНИЯ ВЫХОДА ЭЛЕМЕНТАРНОЙ СЕРЫ ИЗ СЕРОВОДОРОДА И ДИОКСИДА СЕРЫ

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Аннотация. *Актуальность.* Оптимизация процесса Клауса является важной задачей для повышения выхода элементарной серы из сероводорода и диоксида серы, а также для улучшения качества дисперсного продукта. Данное исследование направлено на увеличение выхода элементарной серы и уменьшение максимального размера ее частиц за счет контролируемого снижения пересыщения в аппарате. Дополнительно рассматривается инженерная методика, позволяющая прогнозировать фракционный состав дисперсных продуктов десублимации при варьировании технологических параметров. *Цель.* Повысить выход элементарной серы в цикле установки Клауса путем оптимизации режимов работы десублимационного конденсатора и определить параметры, обеспечивающие получение чистой серы с заданными дисперсными характеристиками. *Методы.* Ключевым технологическим приемом выступает десублимационная конденсация, предполагающая охлаждение газа до температуры ниже точки плавления серы, при котором пары минуют жидкую фазу и кристаллизуются непосредственно в твердое вещество. В рамках исследования разработан новый подход к управлению десублимацией, включающий два последовательных этапа. На первом этапе в исходной парогазовой смеси при постоянной температуре плавно понижают давление до достижения критического показателя. На втором этапе при неизменном давлении проводят интенсивное охлаждение среды до температуры точки росы. Такой метод позволяет получать узкофракционный ультрадисперсный порошок серы при снижении энергетических затрат на процесс. *Результаты и выводы*. Установлено, что управляемое снижение пересыщения позволяет стабилизировать фракционный состав конечного продукта и улучшить его качественные характеристики. Предложенный подход обеспечивает получение тонкодисперсной элементарной серы и может быть адаптирован для десублимационного получения порошков различных веществ. В ходе исследования особое внимание уделено влиянию степени пересыщения на характеристики продукта и кинетические закономерности процесса кристаллизации. Сформулированы рекомендации по модернизации технологической линии Клауса, предусматривающие размещение десублимационного конденсатора перед второй ступенью скруббера. Реализация предложенного решения позволит повысить выход элементарной серы, улучшить дисперсные характеристики продукта и повысить технологическую эффективность процесса переработки сероводородсодержащих газов..

Ключевые слова: десублимационный метод, процесс Клауса, элементарная сера, кристаллизация, тонкодисперсный порошок

Introduction. Currently, the processing of hydrogen sulfide contained in natural gas and petroleum feedstocks, as well as in industrial waste gases, is a mandatory step for industrial safety (Ayapbergenov, 2012; Chumakova et al., 2017; Golubeva, 2015). The high toxicity of H_2S and its ability to convert into SO_2 during combustion necessitate its disposal to obtain useful products, the main one being elemental sulfur (Golubeva, 2015; Golubeva et al., 2017).

The historically established Claus technology has remained the basic solution for these purposes for over a century (Ayapbergenov, 2012; Shirokova, 2010). However, modern environmental requirements and the need to increase the depth of feedstock processing dictate the need for its modernization and the search for alternative approaches (Svirina and Meshkov, 2020; Shermatov et al., 2020). One such promising direction is the use of desublimation for sulfur capture. An alternative method for extracting solid sulfur from gas mixtures containing its vapor is based on the principle of desublimation (Generalov, 2006; Dairabai et al., 2016). The key feature of this method is that when the vapor-gas flow is cooled below the sublimation temperature (approximately 120°C at standard pressure), sulfur vapor crystallizes directly onto cooled surfaces, forming a dense layer of solid product (Dairabai et al., 2016; Dosmakanbetova and Orymbetov, 2021). In this process, the liquid phase, characteristic of traditional condensation, is completely absent during the phase transition.

This technology demonstrates its greatest efficiency in the final stages of gas purification. The efficiency of sulfur recovery at low partial pressures has been confirmed in experimental studies of fine dispersion formation and condensation processes (Dairabai et al., 2016; Dosmakanbetova and Orymbetov, 2021). Under conditions where the partial pressure of residual sulfur vapor is low, desublimation allows for their capture with high efficiency. As a result, the overall sulfur recovery rate within a plant can reach 99.9% and even exceed this value (Chumakova et al., 2017; Golubeva et al., 2017).

Literary review. As is known, desublimation is a phase transition from vapor to solid state on a cooled surface, occurring at a pressure below the triple point (Generalov, 2006; Arkhipova et al., 2011). When the system temperature reaches the crystallization onset threshold, the component begins to transition into the solid phase, and this process completes at the full crystallization temperature (Arkhipova et al., 2011).

In other words, crystallization occurs within a temperature range bounded by critical values. At the eutectic point, the system becomes invariant, meaning it loses degrees of freedom (Arkhipova et al., 2011; Evstifeev, 2018). This corresponds to classical thermodynamic descriptions of phase equilibria in multicomponent systems (Evstifeev, 2018). Initially, the system is cooled while maintaining a constant temperature, and the pressure within it is gradually lowered to a critical level. In the second stage, with the pressure fixed at the achieved level, the mixture is rapidly cooled to the dew point temperature (Dosmakanbetova and Orymbetov, 2021).

Materials and methods. The proposed method is precisely based on controlling the process by following the described sequence of pressure and temperature changes (Dairabai et al., 2016; Dosmakanbetova and Orymbetov, 2021). A graphical interpretation of the process is shown in figure 1, which displays the working line of desublimation. The diagram highlights the regions where solid, liquid, and gaseous phases exist. The composition of the liquid phase evolves along the line up to the eutectic point, corresponding to the crystallization temperature (Arkhipova et al., 2011). Changes occurring in the system in this section can lead to uneven crystal growth and local fluctuations in chemical composition (Burd and Jackson, 2002; Bankar et al., 2004).

The cooling of melts is accompanied by the release of crystals of the pure component, while the remaining liquid phase naturally changes its composition along the entire liquidus line (Arkhipova et al., 2011). At this stage, a characteristic feature is the formation of crystals with a wide range of sizes (Burd and Jackson, 2002; Koch and Cohen, 2000). Upon reaching the complete crystallization temperatures, the system represents a mechanical mixture of crystalline phases of various components.

From a thermodynamic point of view, each potential route of phase transformation is characterized by a specific energy barrier (Lefevere, 2006; Oberdisse, 2006). Such behavior is typical for non-equilibrium systems with competing phase transition pathways (Lefevere, 2006). The actual implementation of the process always follows the path that ensures minimal energy expenditure.

For the case of desublimation, the fundamental requirement is to cross the phase interface while bypassing the liquid region. To reliably avoid the appearance of a liquid phase, the process control must be conducted in the parameter region located to the right of the dew point (Dosmakanbetova and Orymbetov, 2021). As demonstrated by the working line of the process, the starting point O lies in a region on the phase diagram that is to the right and below the curve bounding the liquid state.

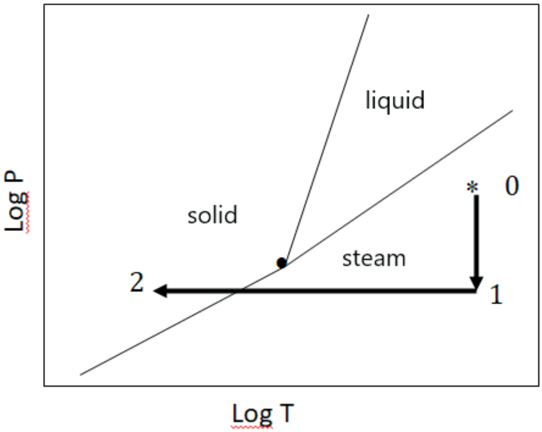


Figure 1. The working line of the desublimation process.

The sequence of operations in process control is as follows. From the starting point O, a smooth reduction in the pressure of the vapor-gas mixture is initiated to point 1, corresponding to the critical value for this component. After that, a forced reduction in temperature is carried out from point 1 to point 2. Upon reaching the calculated temperature level, which coincides with the critical value, the formation of desublimate in the form of an ultrafine powder occurs (Dairabai et al., 2016; Generalov, 2006).

This approach makes it possible to reproducibly obtain a powder material with a consistently narrow fractional composition, possessing specific properties characteristic of this particular parameter range (Evstifeev, 2018; Oberdisse, 2006). This is critical for ensuring product quality in fields such as pharmaceuticals, nanotechnologies, radio electronics, and other high-tech industries.

The specificity of the phase diagram of sulfur lies in the possibility of the existence of several solid-phase modifications, the formation of which is determined by the conditions of the phase transition (Arkhipova et al., 2011). For illustration, consider the case of a vapor-gas mixture containing sulfur vapor with initial parameters: T=392.5 K, P=2.4 Pa. The pressure is smoothly reduced to 2 Pa (a critical value close to the dew point), then the temperature is intensively lowered to 386 K. At this temperature, according to the diagram in Figure 2, the process of sulfur vapor desublimation begins.

Moreover, in the parameter range from T=427.2 K, P= 30 kPa to T=368 K, P=0.5 Pa, monocrystalline sulfur (particle size 5 microns) is formed, and in the range from T = 386 K, P=1.729 Pa to T=368 K, P=0.5 Pa - rhombic sulfur with a particle size of 2,5 micron (Arkhipova et al., 2011; Generalov, 2006)s.

Consequently, the proposed method of controlling desublimation ensures the production of a narrowly fractionated ultrafine powder while optimizing energy consumption.

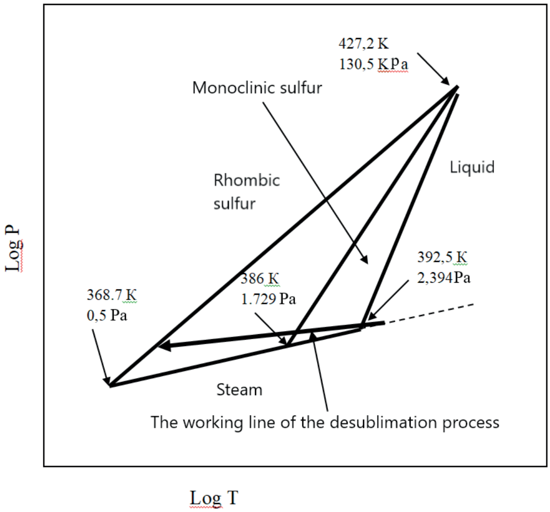


Figure 2. Phase diagram of sulfur.

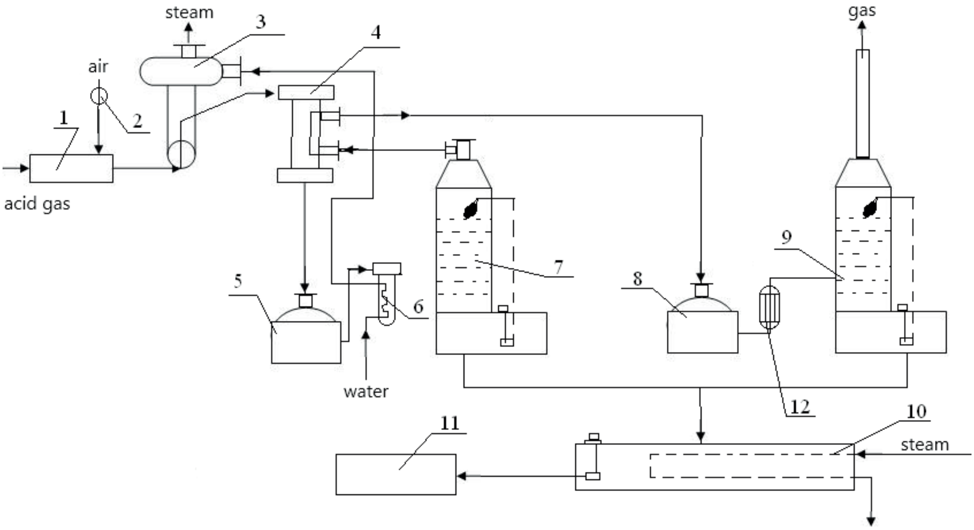
Results and discussions. For conducting experimental studies on the process of sulfur extraction by the desublimation method, a laboratory setup was developed and assembled, the schematic diagram of which is shown in Figure 3. It includes the following functional blocks:

A gas mixture preparation unit equipped with a system of precision mass flow controllers for supplying hydrogen sulfide, sulfur dioxide, nitrogen, and water vapor.

A flow-through tubular catalytic reactor filled with an industrial aluminum oxide-based catalyst. The operating temperature range in the reactor is from 200 to 300°C.

A pre-condensation condenser designed to separate the bulk of the sulfur in the liquid phase. It is an air-cooled heat exchanger that maintains a temperature in the range of 130–140°C.

An experimental desublimation condenser allows for precise regulation of the coolant temperature to control the process of sulfur crystallization from the gas phase.



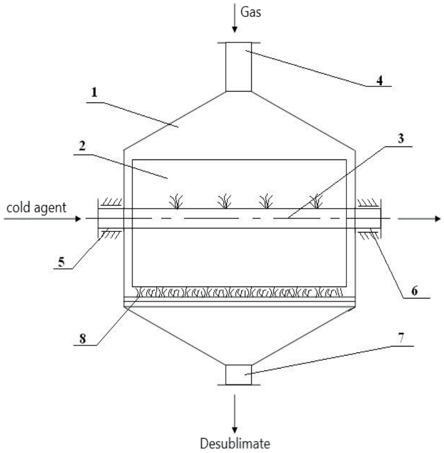
1 - reactor; 2 - blower; 3 - recovery boiler; 4 - acid gas heater; 5,8 - reactor with catalyst;
6 - economizer; 7,9 - scrubbers; 10 - sulfur collector; 11 - commercial sulfur tank;
12 - desublimation condenser.
Figure 3. Technological scheme of purification of hydrocarbon gases from hydrogen sulfide.

The basic Claus technology, implemented in its classic design, ensures effective neutralization of hydrogen sulfide to produce commercial sulfur, achieving a recovery rate of up to 99.9%. The technological scheme involves the sequential passage of gases leaving the combustion chamber through two reactors. In the presence of a catalyst, a reversible reaction between H_2S and SO_2 takes place in them, the products of which are water and free sulfur. At the outlet of the second reactor, up to 96% of the sulfur is in a free state. To recover the sulfur remaining in the gas phase after each reaction stage, the gas stream is cooled to a temperature below the condensation point of sulfur. After separating the liquefied sulfur in a separator, the gas stream between stages is reheated to the temperature required for the next conversion stage (Ayapbergenov, 2012; Shirokova, 2010; Golubeva et al., 2017).

Temperature control of gas streams in the Claus process flow scheme is based on the principle of condensation cooling. The gas leaving the furnace at a temperature of 1125°C passes through a specially designed cooler before being fed into the first reactor, where it is cooled to 280°C (Ayapbergenov, 2012). At this temperature, the main reaction of converting sulfur-containing compounds into elemental sulfur proceeds in the first reactor.

The reaction mixture leaving the first reactor at 313°C is cooled in a heat exchanger to 175°C and enters a separator. After separating the liquid sulfur, the gas stream is heated to 200°C and sent to the second reactor, loaded with a highly active alumina-based catalyst, where further oxidation of residual sulfur compounds occurs. The gas leaving the second reactor (temperature 232°C) is cooled in the next cooler to 165°C. At this stage, the sulfur recovery rate is 96%. The stream is then sent for repeated separation. In actual production conditions, packed scrubbers are often used instead of traditional separators, providing more efficient gas cooling and separation of condensed sulfur.

In order to optimize the operation of the scrubber 9 (figure 4), obtain fine sulfur and increase the degree of its extraction, a heat exchanger device 12, which is a rotating drum with internal cooling, was included in the circuit in front of the scrubber.



1 – casing; 2 – drum; 3 – shaft; 4 – gas inlet nozzle; 5 – coolant inlet nozzle; 6 – coolant outlet nozzle; 7 – outlet nozzle; 8 – removable device.
Figure 4. Desublimation condenser.

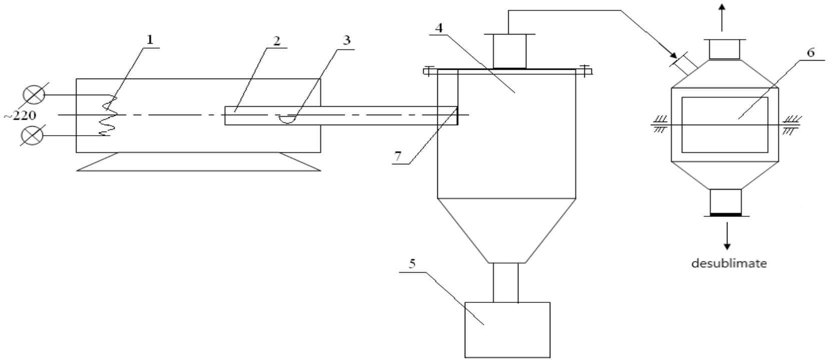
The process gas, containing sulfur and hydrogen, enters the condenser where it is cooled upon contact with the drum surface. The inlet temperature range is 300–380°C, and the outlet temperature range is 120–180°C. The condensation efficiency reaches 95–99.8% with a hydraulic resistance of 250 Pa (Chumakova et al., 2017). The layer of sulfur formed on the drum is removed by a scraper located at the bottom.

During industrial tests, with an inlet gas temperature of 300–365°C and a cooling water temperature of 80–90°C, the hydraulic resistance of the apparatus was about 300 Pa, and the condensation efficiency was at the level of 95–99%.

The obtained data confirm the functionality of the design and allow recommending it for use in schemes focused on the production of condensation-sublimation products.

The process of desublimation synthesis of ultrafine silica powder was chosen as the object of study. During the work, the influence of the supersaturation degree on the kinetic patterns and final characteristics of the obtained product was evaluated.

The experiments were carried out on a laboratory bench, schematically shown in figure 5. The experimental procedure included the following stages. A ceramic reactor 2 was placed in a tubular furnace 1, inside which a weighing bottle 3 with a sample prepared according to the standard method was installed. After turning on the heating and reaching the specified temperature regime, the gate 7 was opened. The resulting vapor-gas flow was directed into a container 4, where phosphorite deposition occurred, and the non-condensed silica vapor was discharged into a condenser 6. Upon contact with the cooled surface of the rotating drum, the vapor desublimed, after which the solid product was scraped off and collected. The temperature range in the furnace varied from 400 to 800°C. During the research, it was found that intensive release of SiO_2 begins upon reaching a temperature of 450°C, which is the threshold for this process.



1 – furnace; 2 – ceramic tube; 3 – sampler; 4 – container; 5 – hopper; 6 – condenser; 7 – damper.
Figure 5. Experimental setup diagram.

The resulting product was collected in glass bottles and submitted for analysis, including determination of chemical and particle size distribution, as well as crystal structure. Sublimations of samples synthesized in the temperature range of 450–600°C were processed.

Based on pressure measurements, a relative supersaturation curve was calculated and plotted, as shown in Figure 6.

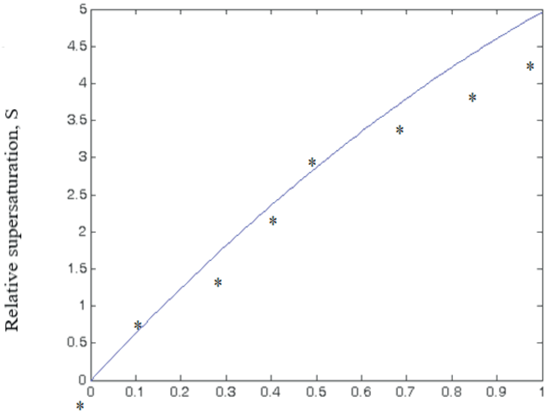


Figure 6. The effect of supercooling on the relative supersaturation of silicon dioxide vapor during desublimation.

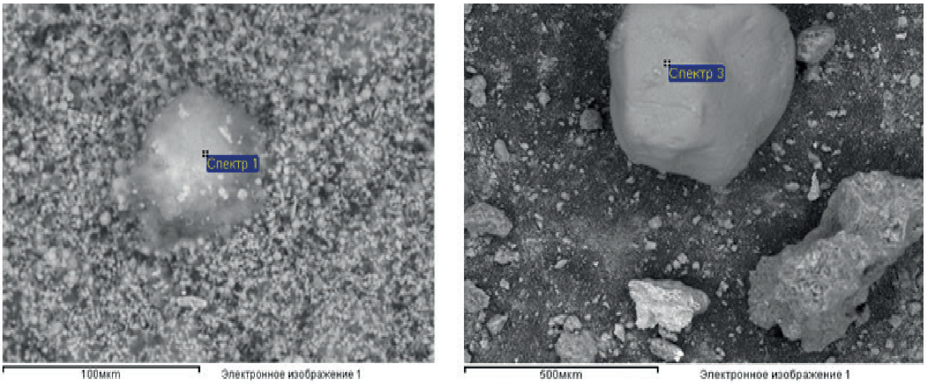


Figure 7. Micrograph of desublimation samples of sublimates.

The graph also displays the results of theoretical calculations and experimental data. A comparison of these data demonstrates good agreement: the deviation is within 10%.

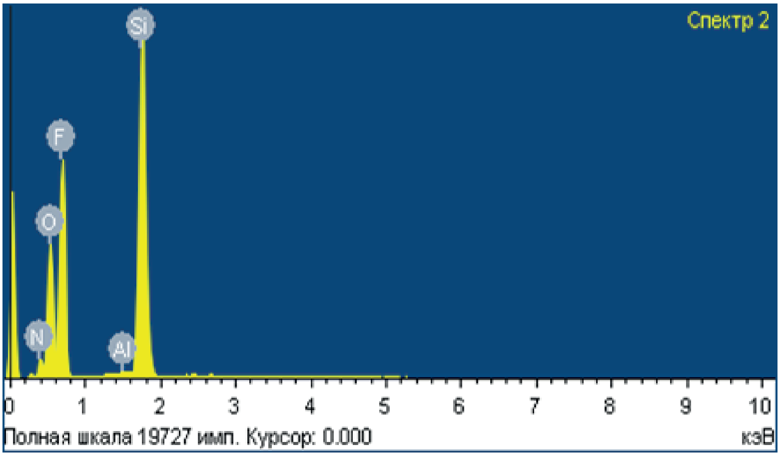


Figure 8. Results of X-ray spectral microanalysis of sublimates after desublimation.

The illustrations in Figures 7 and 8 demonstrate ways of presenting experimental data using electron microscopy and X-ray spectral analysis, respectively.

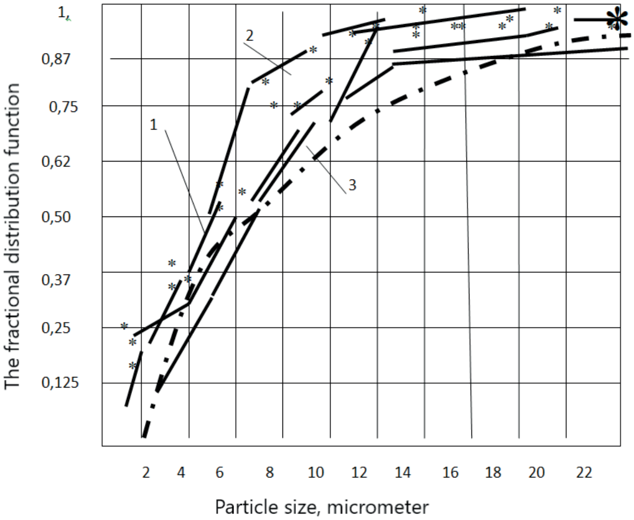
A complete sample of the experimental processing results is provided in the appendices. A total of 33 distillates were obtained from five initial samples, each of which was analyzed. The particle size distribution was determined by counting their number on micrographs using a 2 micron mesh.

The characteristic distribution curves (in fractions) are shown in Figure 9.

The experimental data for all 33 sublimates demonstrate a scatter not exceeding a band width of 0.225. The maximum deviation of the measured values from the theoretically calculated ones is observed in the size range of 6–10 µm and amounts to 25%.

Analysis of the curves allows us to identify two stages of sediment formation: a sharp increase in the fractional function for particles up to 8–10 µm in size and a plateau after 15–19 µm. Based on this, the average size of silica nucleates on the substrate is estimated to be 2–4 µm.

The theoretical model, according to which the desublimation process includes a stage of rapid nucleation and a stage of slowed diffusional growth, has been experimentally confirmed. The average size of nucleates on the quartz substrate was recorded at 2.4 µm.



1 - sample 1; 1; 2 - sample 3; 3 - sample 5; dotted line - theoretical assessment.
Figure 9. Fractional distributions of SiO_2 particles after desublimation of sublimates on a substrate (averaged over 33 samples).

The experimental data convincingly demonstrate that the use of desublimation condensation is a highly effective method for the final treatment of tail gases from Claus plants (Svirina and Meshkov, 2020; Shermatov et al., 2020). The dynamics of the process were investigated: it was established that the capture efficiency remains at a stable level during an operating cycle lasting 5–6 hours. After this time, regeneration of the apparatus surface is required by melting the accumulated sulfur layer. In this regard, a cyclic operating mode is recommended, including sequential phases: product accumulation, melting, and draining.

The proposed set of optimization measures — maintaining the stoichiometric H_2S/SO_2 ratio at 2:1, regulating the temperature in the catalytic reactor, and incorporating the desublimation stage — allows increasing the overall processing efficiency to 99.5%. This ensures a reduction in harmful emissions and an increase in the yield of commercial sulfur without the need for a major reconstruction of existing equipment.

The following areas have been identified for further research: studying the influence of impurities (hydrocarbons, aromatic compounds) on the kinetics of desublimation, as well as the development of heat exchanger designs resistant to fouling by solid sulfur.

Conclusion. The desublimation method for sulfur has proven itself as an effective and promising tool for capturing a valuable component from hydrogen sulfide and acid gases. This method makes it possible to obtain a product with a high degree of purity while simultaneously minimizing environmental damage. The improvement of technologies in this direction will contribute to expanding the field of application of desublimation in various industrial sectors.

In the technological chain, desublimation plays the role of a highly efficient finishing module, ensuring deep purification of emissions and the production of higher quality solid sulfur.

Consequently, integrating in-depth optimization of the classic Claus process with the introduction of a desublimation stage at the final step is the most rational strategy for creating environmentally safe and cost-effective complexes for hydrogen sulfide processing.

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