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CURRENT USSR TECHNOLOGICAL PROBLEMS IN THE FIELD OF INORGANIC CHEMISTRY IN CONNECTION WITH THE EXECUTION OF THE FIFTH FIVE-YEAR PLAN

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Technological development of the chemical industry should proceed along the following lines:

1. Development of new, highly efficient processes.
2. Development of methods for improving the efficiency of existing types of production.
3. Development of new types of fertilizers and of various chemicals to satisfy the needs of agriculture and farming in every respect.
4. Expansion of the range and variety of consumers goods manufactured at chemical enterprises.
5. Many-sided utilization of crude materials.
6. Development of new types of highly efficient production equipment.
7. Search for corrosion-resistant materials which are not in short supply and can be used in the construction of chemical-production equipment.
8. Introduction of a maximum degree of mechanization and automatization into production processes.
9. Purification and rational utilization of liquid effluents and of noxious gases released into the atmosphere.

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Technological Problems in the Field of Sulfuric-Acid Production

The USSR chemical industry may point to considerable achievements in sulfuric-acid technology. Investigations of the kinetics of the burning of pyrites have resulted in multiplication of the efficiency of mechanical pyrite furnaces by more than two. On the basis of research on the kinetics of the nitrose process, the yield of acid per unit tower volume could be increased on the average by more than twice in 1953 in relation to 1940, while the yield at certain plants has even been raised to a still higher level. As far as contact sulfuric acid is concerned, domestic vanadium catalysts and high-capacity catalytic converters have been developed and introduced. During recent years, extensive research has been carried out on the absorption of sulfuric acid anhydride and the purification of burner gas from harmful admixtures. In cooperation with the Institute of Automatics and Telemechanics, Academy of Sciences USSR, extensive work on the complete automatization of the contact process is being carried on.

At present, the principal crude material for the production of sulfuric acid is flotation pyrite, which is burned in mechanical furnaces or furnaces for the burning of dust [flash roasters].

Unfortunately, calcined pyrite is not yet being used as a metallurgical crude material, although there are no serious technical obstacles to its smelting. The Institute of Metallurgy, Academy of Sciences of Ukrainian SSR, has successfully completed an investigation on using chalk fines, which are a by-product of soda manufacture, for combining with ores that are in the form of dusts. The agglomerate of chalk and ore is then converted in blast furnaces. The Ministry of Chemical Industry USSR regards it as essential and urgent that work be done on adapting this process to calcined pyrite. Application of this process to calcined pyrite will take care of the cumbersome waste products that accumulate at chemical plants which produce sulfuric acid and calcined soda. Another possibility is the use of calcined pyrite as an additive in the manufacture of cement.

While considerable work has been done on the kinetics of pyrite burning, the chemistry of the burning of pyrite has not yet been investigated adequately. This impedes further work on the improvement of the efficiency of furnaces. The investigation of various systems formed in the charge during the process of oxidation is also of importance. This refers primarily to the systems FeS-SiO_2 , $\text{Fe}_3\text{O}_4\text{-SiO}_2$, $\text{FeS-Fe}_3\text{O}_4\text{-SiO}_2$, FeS-FeO-SiO_2 , and $\text{FeS-Fe}_2\text{O}_3\text{-SiO}_2$.

At present, elemental sulfur is used to a comparatively limited extent for the production of sulfuric acid in the USSR. In connection with the discovery of new deposits of elemental sulfur, one may expect that sulfur will be used on a most extensive scale as a crude material for the production of sulfuric acid, because sulfur is preferable to pyrite in many respects. For that reason, it is necessary to conduct investigations on the burning of sulfur and of products of the enrichment of ores (sulfur concentrates). In particular, the mechanism of the oxidation of sulfur in the vapor phase has not yet been investigated.

An important task is the development of highly efficient equipment for the continuous melting out of sulfur from ores and from sulfur concentrates. In connection with the extraction of sulfur from the ores of new deposits occurring in carbonate rocks, there is the possibility of producing ground limestone, which can be used for treating acidic soils.

In connection with the expansion of the production of concentrated phosphate fertilizers with preliminary production of phosphoric acid by sulfuric acid extraction of phosphates, phosphorus gypsum [calcium sulfate-calcium phosphate] is formed in large quantities as a waste product. This brings up the problem of recovering sulfuric acid from the phosphorus gypsum. The process for the production of SO_2

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and of cement clinker from gypsum is known. In the case of phosphorus gypsum, phosphoric acid interferes with clinker formation. It is necessary to find additives for the charge which would counteract the harmful effect of phosphoric acid.

In a number of regions of the USSR, pyrrhotines are the only local crude material which contains sulfur. In the burning of pyrrhotines, as distinguished from the burning of pyrites, there is no thermal splitting off of sulfur. Consequently, the material does not become porous, so that the combustion of pyrrhotines is less intensive than that of pyrites. It is necessary to search for methods by which the oxidation of pyrrhotine can be intensified.

In many types of production, e.g., in the petroleum industry, waste sulfuric acid contaminated with organic material is obtained. Utilization of this acid is a very important matter. Occasionally, the sulfuric acid can be used as such, but more frequently, the waste acid has to be decomposed with the formation of sulfur dioxide. It is better to use sulfur for this decomposition than carbonaceous fuel.

In connection with the prospective availability of cheap power from hydroelectric stations, cheap oxygen will become available. The use of oxygen opens up possibilities for improving the efficiency of sulfuric-acid production. It is of particular advantage to use oxygen in burning crude material that contains carbon and sulfur (pyrite combined with coal, waste material from coal enrichment). By using oxygen in oxidizing this material, 100% CO₂ or CO can also be obtained. However, the problem of more complete enrichment of coal pyrite will have to be solved first.

Of current importance is also the development of new types of furnaces for burning crude material that contains sulfur, for instance, furnaces for burning in a "boiling" layer [fluidized solid layer]. In connection with this, development of smoothly operating boilers for the utilization of the waste heat of furnaces in which sulfur-containing crude material is burned becomes of importance. In recent years, a number of methods for cooling calcined pyrite and for its mechanical removal have been developed. Work on the perfection of these methods should be continued.

In connection with the manufacture of sulfuric acid by the tower method, lowering of the expenditure of nitric acid remains a problem, notwithstanding the high level of efficiency which has been achieved in the tower process. High losses of nitric acid not only increase the cost of production, but also form a health hazard in the regions where the plants are located. The finding of effective absorbents for nitrogen oxides becomes of importance from this standpoint. Furthermore, the transfer of the entire tower process from 76% sulfuric acid, which is a relatively poor absorbent of nitrogen oxides, to oil of vitriol, which is a better absorbent of these oxides, ought to be considered.

In the production of contact sulfuric acid, application of active vanadium catalysts and construction of catalytic converters which assure operation at optimal temperatures have resulted in high yields of acid per unit volume of catalyst and a high total extent of catalytic conversion.

To assure a continually increasing production of sulfuric acid to be used in the manufacture of fertilizers and for other purposes, it is necessary to increase by several times the capacity of individual catalytic converters without increasing substantially the diameter of the tube gratings. Good results may be expected in that respect from extensive introduction of a catalyst mass formed into rings. This type of catalyst offers a low resistance to hydraulic flow.

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One must continue work on the improvement of vanadium catalysts, particularly with the view of lowering the temperature of ignition. If this temperature is lowered, simpler designs of equipment will result. It is also necessary to increase further the thermal stability and mechanical strength of vanadium catalysts. A search for cheaper catalyst masses, particularly active natural clays, should be conducted. It is important to create a simplified method for the dry purification of burner gas which would not require prior cooling of the gas resulting from the burning of either pyrite or sulfur.

It would be of interest to investigate the direct oxidation of sulfur to SO_3 without passing through the SO_2 stage. To solve this problem, it is necessary to find a suitable catalyst and to devise a procedure for the effective removal of the heat of oxidation of sulfur. Successful work in this field would simplify the contact process and open the possibility of using the heat of oxidation of sulfur more completely.

Work should be done on the concentration of dilute sulfurous gases going to waste at metallurgical plants, electric power stations, and other types of plants. Here, one cannot limit oneself to the methods which are already being applied, i.e., the ammonia method and the ammonia-acid method. One must find new absorbents for sulfur dioxide, including organic substances which are suitable for that purpose. Of particular interest are methods for the concentration of sulfur dioxide carried out in combination with other processes, i.e., the ammonia method of enrichment, combined with the production of ammonium nitrate; the absorption of sulfur dioxide by zinc oxide pulp, combined with the electrolytic production of zinc, etc.

Hitherto, all investigators had set themselves the task of finding an economic method for the production of 100% SO_2 . However, at a number of installations, it would be advisable to enrich sulfur dioxide partially, i.e., up to a concentration of 7%, and then use it directly for the production of sulfuric acid.

Introduction on a large scale of economical methods for the enrichment of sulfur dioxide and use of cheap oxygen in sulfuric-acid production will increase by several times the output of sulfuric-acid plants.

Technological Problems in the Field of Phosphate-Fertilizer Production

Superphosphate is the phosphorus fertilizer which is most widely used at present. Work done on the improvement of the quality of superphosphate and on methods for its production will remain of importance for a long time to come.

The continuous method of production is used at the superphosphate plants which have been built in recent years. One of the immediate tasks will be application of the continuous method at all superphosphate plants.

Particularly timely is the problem of improving the quality of superphosphate obtained from phosphorites of the Kara-Tau deposit. Since the P_2O_5 content of this crude material is lower than that of apatite, and since furthermore it contains calcium carbonate and magnesium carbonate, the finished product obtained by using an increased amount of sulfuric acid has a relatively low P_2O_5 content and exhibits unsatisfactory physical characteristics. The most important task will be development of methods for the enrichment of Kara-Tau phosphorites, i.e., enrichment in heavy suspensions [suspensions in liquids of high specific gravity], enrichment by chemical methods, etc. The physical characteristics can be improved by treatment with ammonia, i.e., neutralization of the superphosphate's free acidity with ammonia. An experimental production installation for the ammonization of superphosphate is already in operation [at the Kokand Superphosphate Plant].

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In connection with the problem of producing phosphoric acid and concentrated fertilizers from Kara-Tau phosphorites, it is advisable to investigate the system $P_2O_5 - MgO - H_2SiF_6 - H_2O$.

In the production of concentrated phosphorus fertilizers (double superphosphate containing 47-48% of P_2O_5), preceded by extraction of phosphoric acid with sulfuric acid, it is very essential to obtain directly concentrated phosphoric acid and have the calcium sulfate crystallize out in the form of anhydrite.

In addition to double superphosphate, "precipitate" (containing up to 45% of P_2O_5) and ammophos (containing up to 50% of P_2O_5 and 12% of N) will be produced within a few years. In connection with this, one must develop methods of decomposing apatite and phosphorites not only with sulphuric acid, but also with nitric and hydrochloric acids. One should pay particular attention to applying practically the method of the decomposition of phosphates with nitric acid. If this method is applied, concentrated phosphates ("precipitate"), mixed fertilizers (nitrophoska), and nitrogen fertilizers (calcium nitrate and ammonium nitrate) are obtained, and the chemical energy of nitric acid is utilized twice.

The extent of the production of phosphorus fertilizers is still restricted by the level of production of sulfuric acid. For this reason, it is necessary to develop the production of phosphates that are assimilable by plants and produced without the use of sulfuric acid, i.e., the so-called thermal phosphates. At present, a method for producing fused magnesia phosphates which contain up to 30% of P_2O_5 is being developed.

Processes are being developed for producing (1) highly concentrated defluorinated phosphates by treating phosphorite with steam in rotary furnaces without melting the phosphate, and for (2) defluorinated fused phosphate in shaft furnaces. Of definite interest is the thermal method of producing calcium metaphosphate and the complex conversion of phosphorites, together with sodium sulfate and nepheline, into thermal phosphate.

In connection with the production of various thermal phosphates, it became necessary to investigate the mechanism and kinetics of the defluorination of phosphates, the fusibility in the system $CaO - MgO - P_2O_5 - SiO_2$, the fusibility and viscosities in the system $CaO - Al_2O_3 - P_2O_5 - SiO_2$, etc.

Another source of phosphate fertilizers is formed by phosphate slag produced at metallurgical plants. Efforts should be made to increase the P_2O_5 content of phosphate slags to 16-18%.

With the reduction in the cost of electric power, the possibilities of the production of elemental phosphorus and of phosphorus fertilizers on the basis of elemental phosphorus are increased. The advantage of manufacturing fertilizers, starting with elemental phosphorus, is that one may convert practically any naturally occurring phosphate into high-quality fertilizer. There are many methods for improving the efficiency of the electrothermal production of phosphorus which reduce the use of power and the cost of the product, because a number of other products are obtained together with phosphorus. Some of these methods are use of briquetted charges; simultaneous production of phosphorus, aluminum oxide, alkalis, fluorides, and cement from apatite-nepheline, apatite-clay, apatite-bauxite, and other charges; simultaneous production of phosphorus and calcium carbide; utilization of gases of phosphorus furnaces; and utilization of the slags of phosphorus production.

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A number of problems that arise in connection with the oxidation of phosphorus must be solved. For instance, research must be done on (1) the oxidation of phosphorus by means of water vapor, with simultaneous production of hydrogen, and (2) oxidation with water under pressure. To solve the problems involved in the technology of phosphorus production, it is necessary to subject to theoretical study the mechanism of the reduction of phosphates, the kinetics of the process of phosphorus distillation, and the effects of various additions to the furnace charge.

Utilization to the utmost degree of the fluorine contained in phosphates and extension of the range of the fluorides produced are also of importance. One should manufacture not only sodium fluorosilicate, as has been done until recently, but also sodium fluoride, calcium fluoride, cryolite, and other fluorine compounds.

Technological Problems in Connection With the Production of Ammonia and of Nitrogen Fertilizers

The range of nitrogen fertilizers being produced is in the process of expansion during the period of the current Five-Year Plan. In addition to the production of ammonium nitrate, which is the principal nitrogen fertilizer, the production of calcium nitrate and of calcium-ammonium nitrate is being developed at present. In regard to the extent of the production and application of ammonium nitrate, which is a highly concentrated fertilizer containing 35% nitrogen, the USSR occupies the foremost place in the world. The quality of this product has been greatly improved during recent years. At present, most of the ammonium nitrate is being supplied in the form of a noncaking product.

It is necessary to develop more efficient and more economical methods for the production of sodium nitrate and potassium nitrate on a large scale, so that these salts may be applied not only for technical purposes, but also as fertilizers.

Of interest are the new methods for the production of sodium nitrate which are being developed, i.e., the method of cation exchange between NaCl and calcium nitrate on ion exchange agents, the direct decomposition of $KC\bar{N}$ with nitrogen oxides, and the double decomposition of ammonium nitrate with potassium chloride.

Urea is a highly concentrated fertilizer, which is especially suitable for the extraradical supplemental fertilization of plants [for use as a fertilizer on rootless saplings?]. However, because of the high cost of urea and the great demand for this chemical on the part of the industry, particularly for the production of plastics, it is not used extensively in agriculture. Measures for reducing the cost of the production of urea should be taken.

A new catalyst which contains a promoter has been developed for the production of hydrogen to be used in the ammonia synthesis. With the use of this catalyst, the temperature of conversion of CO is lowered, the degree of conversion increased, and the quantity of steam reduced. It is necessary to continue the search for active low-temperature catalysts and to expedite the development of catalytic converters the use of which would assure operation under optimal temperature conditions. In other words, lowering of the temperature and an increase in the degree of catalytic conversion should be achieved. Development of fine catalytic methods for the purification of the gas is also of great importance.

* Although progress has been achieved in this field during the past 15 years, this progress cannot satisfy us completely. Creation of catalysts that are active at lower temperatures and at the same time have a sufficient stability will result in a considerable increase in the production of ammonia and a simplification in the design of synthesis columns.

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Extensive work has been done on the improvement of catalysts and catalytic processes applied in the production of nitric acid. A two-stage catalyst for the oxidation of ammonia, which considerably lowers the amount of platinum that has to be invested at any one time, has been developed and is being introduced. Some results that have been obtained in work on catalysts for the oxidation of ammonia may lead to the complete elimination of platinum.

At present, a method is available for the direct synthesis of concentrated nitric acid by the oxidation of nitrogen oxides with oxygen under pressure. Development of a method for the direct synthesis of concentrated nitric acid with pressure would be of great value. An important task is development of a method for the production of concentrated nitric acid by the direct conversion of concentrated ammonia-oxygen mixtures with the use of oxygen gas. An important factor in increasing the efficiency of the production of dilute nitric acid would be application of a catalyst for accelerating the oxidation of nitrogen oxide during the process of absorption.

The importance of investigations in the field of catalysts can be seen in the example of the nitrogen industry. USSR scientists have developed a number of new catalysts and catalytic processes. Considerable success has been achieved in recent years in the field of the kinetics of industrial reactions. The new subdivision of diffusion kinetics of heterogeneous gas reactions has been created. The ideas on the properties and nature of catalyst surfaces have received further development.

However, in view of the great potentialities which are implicit in the application of catalytic processes, the results achieved hitherto do not satisfy us. At present, the search for new catalysts is conducted empirically. When the theory of heterogeneous catalysis has been developed sufficiently, it will be possible to predict catalytic activity on the basis of theoretical considerations.

Technological Problems in Connection With the Production of Potassium Fertilizers

The principal potassium fertilizer available at present is potassium chloride. However, the chlorine ion has a harmful effect on some crops (tobacco, citrus crops, etc.). This necessitates rapid organization of the production of chlorine-free potassium salts (potassium sulfate, potassium phosphates, sulfates of potassium and magnesium, potassium nitrate). One of the ways of achieving this purpose would be utilization of crude salts mined at the Carpathian potassium deposits. These salts contain potassium sulfate and magnesium sulfate. Several methods for working them up have been proposed. Other, simpler methods for their conversion should be developed, however. The hydrothermic method would be suitable for the production of potassium sulfate by the reaction of epsomite ($MgSO_4 \cdot 7H_2O$) with potassium chloride. By using this method, potassium sulfate, magnesium oxide of high quality, and hydrochloric acid can be produced simultaneously. Using the hydrochloric acid obtained in this manner, the production of "precipitate" [a phosphorus fertilizer] can be organized to advantage. Enormous quantities of epsomite are contained in the brines of Kara-Rogaz-Gol.

In addition to this, there is the intention of producing synthetic potassium sulfate by reacting potassium chloride with sulfuric acid. The hydrochloric acid obtained in this manner may be utilized for the production of "precipitate."

Of interest is the development and introduction of a process in which both potassium sulfate and hydrochloric acid are obtained by reacting potassium chloride with sulfur dioxide in the presence of water, oxygen, and iron cinders [pyrite cinders?] all of which act as a catalyst.

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It is necessary to improve the methods for the production of potassium chloride from sylvinite. The method being applied at present at the chemical plant of potassium combines is very complicated and requires a high expenditure of steam. The State Scientific Research Institute of Mineral Chemical Raw Materials (GIGKhS) has proposed a new method for the enrichment of sylvinite in heavy suspensions [suspensions in liquids of a high specific gravity] in a "hydro-cyclone" [centrifugal classifier?]. The pilot-plant work on this method should be completed within the first 6 months [of the current Five-Year Plan] and funds assigned for the designing of production units.

Another method for the enrichment of sylvinite by flotation is also being tested. The work on the crude potassium salts of the Verkhnekamsk [Upper Kama] deposit should be completed in 1954 and experimental work on the enrichment of potassium salts from other deposits should be carried out.

Technological Problems in the Field of Soda Production

In the field of calcinea-soda production efforts are being made to increase efficiency by introducing technologically superior equipment and by utilizing more fully the initial crude material. Equipment of the bubble-column type is being investigated with the view to improving further the efficiency of the distillation process in soda production. Equipment provided with plates of the sieve type is being tested from the standpoint of its application in various phases of soda production, i.e., in precarbonation, distillation, decarbonation, etc.

Automatization of the technological process is being widely introduced at soda-manufacturing plants. Automatic control procedures are being introduced for control of the carbonation process (distribution of the carbon dioxide among carbonation columns, regulation of the supply of liquid to the columns and of the liquid's flow from the columns, and control of the degree of conversion), regulation of the distillation stage from a distance, and the automatic regulation of the supply of steam to the distillation stage.

One of the problems to be solved in connection with soda production is utilization of the waste calcium chloride.

Of importance is the development of a new technology of the production of sodium carbonate, potassium carbonate, and potassium sulfate from the waste leaching solutions of aluminum oxide production, so that the nepheline, which is used as the initial crude material and from which aluminum oxide, cement, and products of the soda industry can be obtained, will be fully utilized. With this end in view, work is being conducted on the following processes:

1. Carbonation of the leaching solutions of aluminum-oxide production, followed by the production of sodium bicarbonate, with subsequent evaporation of the mother liquor (Scientific Research Institute of Fertilizers and Insectofungicides).
2. Gradual carbonation of the leaching solutions of aluminum-oxide production to produce trona and potassium bicarbonate, followed by gradual evaporation of the mother liquors (Institute of General and Inorganic Chemistry, Academy of Sciences USSR).
3. Polythermal separation of sodium carbonate, potassium carbonate, and potassium sulfate by gradual evaporation of the leaching solutions of aluminum oxide production, followed by cooling (VNIIG and All-Union Institute of the Soda Industry).

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In the caustic soda-chlorine industry, electrolytic cells are being introduced which have a larger capacity and are more economical in operation. To reduce the use of electric power (a measure which is very essential at present), a number of definite problems will have to be solved. Among these are application of higher potentials in the operation of diaphragm-cell and experimental checking and introduction into production of a continuous process of brine purification which will insure a higher degree of purification of the brine.

It is necessary to expedite investigations on the reduction of cathode potentials in industrial electrolytic cells, both by proper selection of the cathode material and by adding suitable substances to the electrolyte; on increasing the stability of graphite electrodes and prolonging their useful life; and on the development of new types of diaphragms which will last longer and can be fashioned within a shorter time.

Completion of the investigation on the transfer of electrolytic cells to operation with a filled cathode space will increase the concentration of alkali in the solutions obtained from the cells and thus reduce the quantity of steam needed for the evaporation of these solutions. This problem should be solved within the current year [1954].

Of great practical significance is the transfer of mercury electrolytic cells to operation at higher current densities. Experimental work has shown that introduction of measures to this end will increase the capacity of the production units and reduce the use of mercury without increasing the use of electric power.

Complete automatization, within the shortest possible time, of the technological processes carried out in the plant departments of electrolysis and evaporation is of great importance. Accomplishment of this task will improve the economic indices of the work done by these departments and will also raise the general cultural [sic] level of the production.

Conclusion

The above outline of specific technological problems does not cover all the tasks which must be accomplished by the chemical industry in the field of inorganic chemistry. Success in accomplishing these tasks depends on maintenance of the correct interrelationship between science and production. A great role in the solution of the problems enumerated in this article will have to be played by the institutes of the Academy of Sciences USSR and the institutes of the individual republics. One may remark in this connection that, as a rule, successful solution of some definite technological problem can be achieved by institutes of the academy only under the condition that after the laboratory phase has been completed and the fundamental relationships have been established, subsequent technological development be carried out in close collaboration with specialized branch industrial institutes.

Of great significance to the success of scientific research work is application of the latest methods of investigation (tracer atoms, X-ray analysis, etc.). If the laboratory work has been done thoroughly and the investigation has been on a high level, successful and speedy introduction of the results into industrial practice is assured thereby.

The rapid rate of increase in the demand for chemical products in many cases precludes spending the time necessary for all the stages of experimental work which were customary hitherto, i.e., model experiment, semiplant-scale experiment, and operation of an experimental installation on a production scale. Carrying out the experimental work through all the stages enumerated is very expensive. One must be more audacious in transferring to full-scale industrial application technical data obtained at relatively small laboratory installations. The transition

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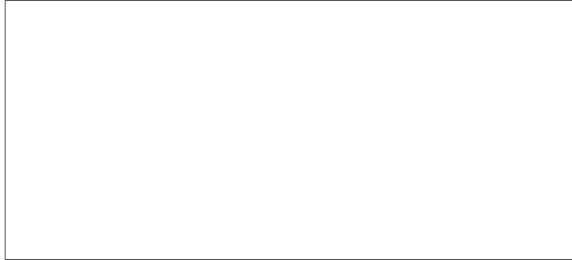
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from an enlarged laboratory installation to production on a large scale is not out of the question. In connection with this, selection and design of the right type of equipment is essential. This can be achieved by creative collaboration of scientists with the technical planning organizations which do the designing [literally, project organizations].

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