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Second Interregional Fertilizer Symposium

Kiev, USSR, 21 September - 1 October 1971
New Delhi, India, 2 - 13 October 1971

Agenda item III/1c

TECHNICAL AND ECONOMIC SURVEY OF NITROGENOUS FERTILIZER PRODUCTION[1/]

by

N.A. Afanasyev

State Institute for Nitrogenous Fertilizers
Ministry for Chemical Industry USSR

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SUMMARY

TECHNICAL AND ECONOMIC SURVEY OF NITROGENOUS FERTILIZER PRODUCTION[1/]

by
N.A. Afanasyev +FANASIEV

State Institute for Nitrogenous Fertilizers
Ministry for Chemical Industry USSR

1. Trends in the production and supply of nitrogenous fertilizers, the share of such fertilizers in the total amount of fertilizer produced and supplied to agriculture, changes in the types of nitrogenous fertilizer produced. Statistics for 1960, 1965, and 1970, plans and requirements for 1975 and 1980.

Discussion of the rapid development of nitrogenous fertilizer production, changes in the range of types produced, future trends in the range of types, particularly in connexion with increases in production. Importance of the production of various kinds of mixed fertilizers.

2. Production cost per unit of nitrogen for different fertilizers (ammonium nitrate, urea, ammonium sulphate, aqueous ammonia, and anhydrous ammonia) at typical enterprises in the USSR according to statistics for 1965 and 1970.

Price levels at which fertilizers are supplied to agriculture.
Additional costs (transport, storage, application).
Cost per unit of nitrogen delivered to the soil.

3. Influence on the cost of nitrogen in fertilizers of manufacturing capacity and production technology for ammonia, nitric acid, and various fertilizers. Cost

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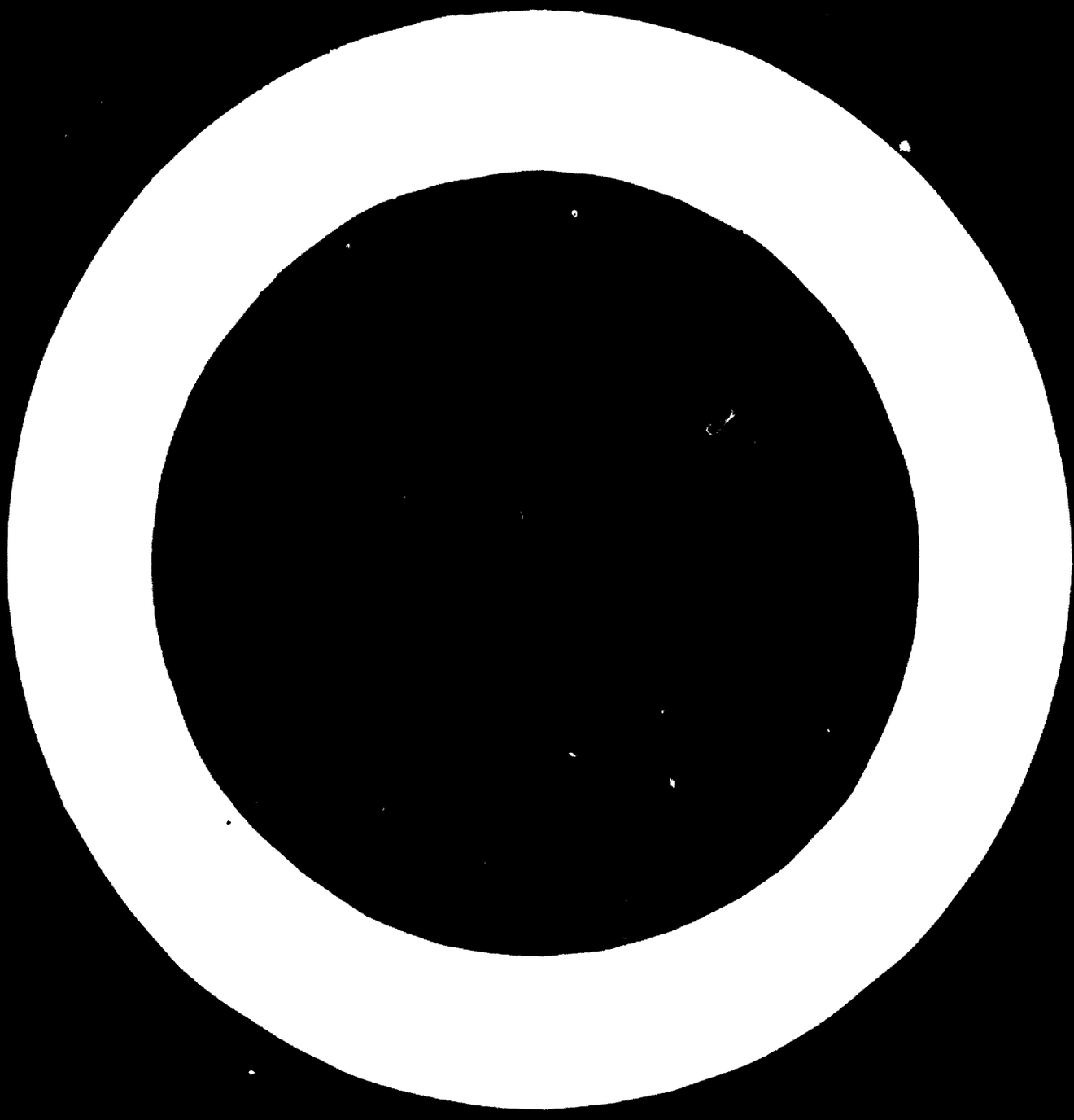
statistics according to design data:

(a) Comparative cost of nitrogen in ammonium nitrate and urea;

(b) Comparative cost of nitrogen in solid and liquid fertilizers.

4. Influence of the cost of nitrogen on mixed fertilizers.

5. Recommendations.



Production of mineral fertilisers in the Soviet Union has been increased considerably in a few years and will increase further in the following ten years.

The production development can be traced by the table below.

	1960	1965	1970	Design 1975	Design 1980	Production growth, percent in 1970 to 1960	Production growth, percent in 1980 to 1970	Note
1	2	3	4	5	6	7	8	9
Production of mineral fertilisers	3.3	7.4	13.1	22.2	36.1	397	275	
including:								
Nitrogenous	1.0	2.7	5.4	7.9	13.0	540	241	
Phosphorous	1.2	2.3	3.6	5.7	10.5	300	292	Including ground phosphate rock
Nitrogenous fertilisers, percent	30	36.5	41.1	36	36	-	-	
Supply of mineral fertilisers to the agriculture	2.62	6.3	10.4	18.1	30.6	398	294	

1	2	3	4	5	6	7	8	9
Including:								
Nitrogenous	0.77	2.3	4.6	6.8	11.3	600	246	
Phosphorous	1.09	2.1	3.2	4.8	9.5	294	297	Including feed
Nitrogenous fertilizers, percent	29.4	36.5	44.3	37	37	-	-	
$N : P_2O_5$ ratio	1:1.4	1:0.91	1: 0.89	1: 0.7	1: 0.84	-	-	

Due to significant rise of natural gas production and development of the gas network there was no feedstock limitation on the rise of the ammonia and nitrogenous fertilizers production growth.

Conditions of phosphorous fertilizer production development were not so favorable. As a result, nitrogenous fertilizers prevail on the market, though the demand sets the desirable $N : P_2O_5$ ratio at about 0.9.

The four-fold increase of fertilizer production in the last ten years together with other contributing factors results in an increase of the agricultural production, which cannot be attributed to the extension of the sowing area amounting for the period to only about 3 percent. Yields of main crops have increased as follows (in 100 kg/hectare per annum):

	1955-60	1966-70
Grain crops	10.1	13.7
Sugar-beet	184	227
Cotton (raw)	20.5	24.1
Vegetables	101	131
Sunflower	9.1	13.1

The further agricultural production growth will also be attained mainly due to the yield increase, which ought to be secured by the further increase of the fertilizer production and by better application practice; e.g. the grain crop yield is designed to rise by 1975 by 400 kg/ha or almost by 30 p.c.

Not only the total fertiliser production has been increased, but the range of fertilizers produced has been extended considerably, too, with particular accent on high-grade fertilizers and nitrogenous liquid fertilizers. The demand for complex fertilizers is not enough covered by now, which results in the necessity of preparing fertilizing mixtures before the application.

The change in the production structure is shown in the following table.

	1960	1965	1970	Ratio 1970/1960	Note
Ammonium nitrate	73.3	55.0	44.5	2.7	
U r e a (46 p.c.N)	2.1	17.1	27.4	31	
Complex fertilizers (11 to 17p.c.N)	-	1.0	3.7	-	
Ammonium sulphate (20.5 p.c. N)	17.9	10.0	7.3	2.2	
Liquid fertilizers (20 to 32 p.c.N)	2.8	14.0	14.5	5.4	Mainly aqua ammonia
Other	3.9	2.9	2.6		
Total	100.0	100.0	100.0		

It is known, that ammonium nitrate had been used as a nitrogenous fertilizer on a large scale first in the Soviet Union, and this experience was lately used in other countries.

It is also known, that the effective application of ammonium nitrate is possible only provided the product is of a high quality, its essential characteristics being absense of caking. There are many methods of producing free-flowing ammonium nitrate. Basically, these are prilling of highly concentrated melt (99.7-99.8 p.c.), improvement of prill stability by the addition of magnesium nitrate or ammonium sulphate or by coating with a surfactant, e.g. dispersing additive "HF", and cooling of the prills.

Finished product shall be packed in polyethylene or laminated paper bags. Due consideration shall be given to the elimination of fines and to coating operations.

All the methods mentioned above increase the cost of ammonium nitrate, but enable a considerable saving and reduction of labour requirement at the stage of application.

The development of urea production in the USSR was aimed at the supply of an additional feed source (to make up for the lack of protein in the cattle feed). However, a decision has been made later to solve the above problem by the development of synthetic protein production and by extension of the natural protein resources, and by now the bulk of the urea produced is used as fertilizer.

Prilled urea is notable for good physical properties, and quite stable in the storage both in paper bags and in bulk.

The following complex fertilizers are produced by the Soviet industry:

	Content, percent		
	N	P	K
Nitroammophoska	17	17	17
Nitroammophos	23.9	24.8	
Nitrophoska	11	11	11
Ammophos	11.5	40	
Diammophos	19	48	

Research work is being made on the development of carboammophoska process.

Also, produced in the USSR are such complex/mixed fertilizers as those on the basis of ammonium nitrate, superphosphate, and potassium chloride (another plant produces similar fertilizer based on urea); mixed fertilizers based on straight fertilizing materials are produced on several special plants located in the consumption areas.

Ammonium sulphate is produced on the basis of the coke oven gas and as a by-product of caprolactam plants, on the acetylene-based acrylonitrille plants, and on the plants using the processes involving by-production of ammonia-rich gas containing sulphur dioxide as an impurity.

Among the liquid fertilizers aqua ammonia is applied in the USSR most widely. The aqua ammonia production amounted to 770,000 ton in 1970 (based on N). Several plants have been designed specially for the aqua ammonia production. By now they are under extension and produce other fertilizers, too.

Anhydrous ammonia is applied to-day only on the experimental scale, but its application is to be widened.

There are plants producing: a) carbamate solutions on the basis of urea melt, ammonia gas, and carbon dioxide; b) nitrogen solutions based on ammonium nitrate and urea (30p.c.N); c) complex liquid fertilizers on the basis of ammonia, phosphoric acid, urea, and potassium chloride (9 - 9 - 9).

Among other fertilizers sodium, potassium, and calcium nitrates can be mentioned.

Calcium cyanamide is used as an intermediate for other chemicals and for cotton defoliation.

Ammonium chloride will be produced at a rate of up to 1.5 p.c. of the total nitrogen production as a by-product of the soda ash process.

The further development of the fertilizer industry will be designed to meet the requirements of the agriculture.

The demand for individual kinds of nitrogenous fertilizers for the present time amounts to the following values (p.c.):

	[illegible]	[illegible]
Ammonium nitrate	42.1	32.4
Urea	12.9	7.7
Complex fertilizers	35.5	54.8
Ammonium sulphate	3.6	2.1
Nitrogen solutions	4.8	2.9
Other	1.1	0.1
	100.0	100.0

Soviet and foreign experience in the field of production and application of fertilizers suggests an increase of urea proportion in the future production pattern, considering it to be a fertilizer equivalent to ammonium nitrate on the most of soils and for the most of crops.

It is also advisable to increase the proportion of liquid fertilizers with anhydrous ammonia being changed gradually for aqua ammonia and to promote the development of complex and mixed fertilizer production.

Below here will be given a comparative evaluation of:

a) ammonium nitrate and urea;

b) liquid and solid nitrogenous fertilizers.

Evaluation of complex fertilizers is beyong the scope of this report.

In the most general sense equivalent amounts of individual nitrogenous fertilizers do not differ much in their effects.

Nevertheless, many crops respond differently to different fertilizers though applied in equivalent amounts, the difference in responce being dependent on the kind of soil, climatic conditions, mode of application (into the irrigation water, by plane, etc.), and at varying posphorus and potassium content of the soil.

Therefore, nitrogenous fertilizers, similar to any other, shall be applied in conformity with the recommendations of agro-chemical services and laboratories.

From the economic point of view fertilizers differ much at the stages of production and application, when compared on the equivalent nutrient content basis.

The economic of fertilizer production is influenced by the process performances.

Liquid fertilizers are most advantageous due to lower production costs, whereas for the application the most favorable are high-grade fertilizers.

It is worth to make a comparative evaluation of:

a) urea and ammonium nitrate

b) anhydrous ammonia, aqueous ammonia, and mixed nitrogen solutions;

c) most advantageous solid and liquid fertilizers.

Nitrogen cost in fertilizers is determined primarily by the cost of ammonia. This amounts in the primary cost of urea to 60 p.c., ammonium nitrate - to 70 p.c. (including ammonia used for nitric acid production), and aqua ammonia - to 45 p.c.

Latest developments in the natural gas-based ammonia production, such as production up-scaling, waste-heat recovery, etc. ensure ammonia cost saving by 30–40 p.c., reducing the contribution of ammonia in the fertilizer cost (e.g. from 70 to 57 p.c. in ammonium nitrate cost).

Thus, saving in ammonia cost ensures a reduction of costs of every nitrogenous fertilizers.

As it was mentioned earlier, ammonium nitrate and urea are nitrogenous fertilizers, produced on the largest scale, ammonium sulphate being a by-product of various processes.

Several existing plants produce urea with nitrogen cost just 10–15 p.c. more, than that in ammonium nitrate. The further improvements of the process will enable complete elimination of the cost difference.

With the view to current developments in the field of nitric acid, ammonium, nitrate, and urea production, it is worth to compare prospective characteristics of the two fertilisers from the points of view of producers and consumers

The table below shows the feedstock requirements per 1 ton of nitrogen

		Urea (from the solution recycle process)	Ammonia nitrate (based on nitric acid from the single pressure process
Ammonia	ton	1.27	1.28
Carbon dioxide (by-product of ammonia plant)	ton	1.63	-
Platinoid catalyst	g	-	0.34(0.15 in other processes)
Power	kWh	440	120
Steam consumption	ton	3.9	-
production	ton	-	3.5
Cooling water	m^3	304	300
Paper bags	piece	48	64
Natural gas (fuel)	Nm^3	-	102

In the following table a comparison is made on the basis of 1 ton N, percent.

	Urea (46 p.c.N)	Ammonium nitrate (34.5 p.c.N)
a) Specific capital cost of the basic plant	102	100
Ditto, of the whole complex	104	100
b) Ditto, of the storage, handling, and application facilities	75	100
Total	95	100
Operating costs		
a) manufacturing	105.5	100
b) handling, storage, and application	75	100
Total	96	100
Equivalent costs (N cost + 0.15 capital cost)	95	100

The above data show a considerable saving storage, handling, and application costs due to a higher nitrogen content of urea (by 25 p.c.). Therefore, the change of urea for ammonium nitrate will result in the overall saving in the national economy of about 5 percent.

In addition to favorable storage and handling properties of prilled urea, consideration must be given to advantages and drawbacks of its manufacturing process.

Among the formers one must mention elimination of expensive platinoid catalyst required to produce nitric acid used as feedstock for ammonium nitrate manufacturing. A considerable success has been made though in the work devoted to the problem of substitution of platinoid by cheaper and more readily available materials. This will enable the elimination of dependence on the imports of platinoid gauzes.

Manufacturing of urea is a more sophisticated process as compared to the nitric acid and ammonia nitrate processes, and according to our experience the former involves much more problems in operation, especially at the plants operated by personnel which has not aquired proper training.

Urea and ammonium nitrate are fully interchangeable as regard the most of crops. However , rice requires urea (or ammonium sulphate),preferably. Ammonium nitrate is not enough adequate for the crop.

On the other hand, according to conclusions made by some of the agro-chemists, the use of urea is not advisable when applied by plane (i.e. without burying into the soil), especially for alkaline soils.

Urea is used successfully for extra-root feeding for the preparation of mixed fertilizers, and as an additive to the cattle feed.

Thus, one must conclude, that ammonium nitrate and urea are quite interchangeable, with certain advantages of urea, and there is not any economic restrictions to the development of the urea production.

Statistical data of last years show a considerable rate of urea capacity growth in many countries.

A significant place is occupied by urea in the world trade.

Among the liquid nitrogenous fertilisers anhydrous ammonia proved to be the most effective.

The table below shows comparable characteristics of anhydrous ammonia and ammonium nitrate, based on 1 ton of nitrogen.

	Anhydrous Ammonia	Ammonium nitrate
Capital costs		
manufacture	50	100
use handling storage, and application	142	100
Total	86	100
Operating costs		
manufacture	93	100
use	106	100
Total	92	100
Equivalent costs (I_{cost} = 0.15 capital cost)	89	100

The resulting total saving is due to the saving at the stage of manufacturing, as far as the direct

application of anhydrous ammonia eliminates the cost of ammonium nitrate manufacture.

On the other hand, direct application of ammonia necessitates the use of expensive storage and application facilities in the region of consumption and the appropriate operating costs and depreciation.

The basic advantage of direct application of anhydrous ammonia proceeds from 2-3-fold labour saving as compared to solid fertilizers at every stage.

Data given in the table above are calculated on the assumption of the optimum anhydrous ammonia supply system plant - basic storage - field, and plant - basic storage- local storage- field with basic-to-local storage capacity ratio of 3:1 and with 4500 t isothermal storage tanks at the basic storages.

Should the supply system pattern be far from that, e.g. local storage tanks be of 50 t capacity and designed for the operating pressure of 16 kg/cm^2 (G), any saving due to the anhydrous ammonia application is lost completely.

Therefore, it is vital to chose an effecient supply pattern using highly economic storages and handling facilities.

It should be noted, that the calculated effect can be obtained only in the case of a large-scale direct application of anhydrous ammonia, when there will be no need in the construction of solid fertilizer plants, and anhydrous ammonia will be accumulated to meet the seson requirements.

Today, when capacity of ammonia plants reaches 200,000-400,000 t/year, the ammonia requirement of appropriate fertilizer manufacturing plants being 100,000-200,000 t/year, elimination of the latters would result in the problem of accomodation of all this quantity of ammonia, or one should provide for the direct application of the amonia produced in excess of the requirements of the reprocessing facilities, e.g. if an ammonia plant capacity is 400,000 t/year, and the ammonia requirement of a complex fertilizer plant is 350,000 t/year, the excess 50 t/year ammonia can be sent for the direct application.

As it was mentioned earlier, the most wide use is made in the USSR of aqua ammonia as a liquid fertilizer containing only 20.5 p.c. N. Aqua ammonia is stored and transported in tanks designed for the pressure of 0.5 kg/cm^2G.

Operating costs for application of aqua ammonia are higher, than those for annydrous ammonia because of lower N content of the former. The general economic indices of aqueous and anhydrous ammonia do not differ much if the distance between production and consumption areas does not exceed 100 km. The longer the distance, the greater an advantage of annydrous ammonia.

Economic advantages of aqueous ammonia in comparison to the solid fertilizers (ammonium nitrate) due to the manufacturing saving are obvious. Nevertheless, a low nitrogen content and nitrogen loss in an eventual failure to keep the design storage conditions make the consumers to

offer a reduction of the aqua ammonia use.

To make full use of the existing storage and application facilities, avoiding the negative effect of low nitrogen content of aqueous ammonia, a proposition has been made to use nitrogen solutions and complex liquid fertilisers. We have an experience of manufacturing nitrogen solutions based on urea synthesis products. The nitrogen content of the final product is maintained at a level of 29 to 32 p.c. according to season, the winter solution being poorer to avoid the risk of crystallysation. According to the data available, carbamate solution can be stored in carbon steel tanks at temperature up to 30°C. Agro-chemists report a high sugar-beet yield after application of carbamate solution.

The economy of the carbamate solution manufacturing can be evaluated in terms of 1 ton N cost (p.c.):

Aqueous ammonia. 100

Carbamate solution 106.5

Prilled urea (bagged) 114

After correction to account for the effects of handling, storage, and application costs the values above will change as follows

Aqueous ammonia 100

Carbamate solution 93

Prilled urea (bagged) 122

Production of carbamates should be assumed reasonable at the plants manufacturing prilled urea.

Nitrogen solutions of various N content can be also prepared on the basis of ammonium nitrate, urea, and ammonia. The presence of ammonium nitrate increases the corrosivity of the solutions and necessitates the addition of inhibitors or the use of stainless steel as the material of construction for all the equipment handling the solutions.

As far as the agriculture needs a vast supply of complex fertilizers, and the use of liquids assures a labour saving, it is reasonable to establish the production of liquid complex fertilizers based on ammonia, phosphoric acid, and potash or on urea and ammonium phosphates.

Conclusions and Recommendations

The production of nitrogenous fertilizers in the USSR was increased for 10 years by 5.4 times, and their supplies to farms - by 6 times. In the following ten years the nitrogenous fertilizer production will rise by 2.4 times.

The development of the nitrogenous fertilizer production enabled a considerable growth of crop yields.

2. For the same period the variety of fertilizers produced was considerably widened, with growing role of high-grade and liquid fertilizers. The Soviet industry produces complex, complex-mixed, and mixed fertilizers, the production of the latters being based on straight fertilizers and located in consumption areas.

3. Complex fertilizers are needed by the agriculture most urgently. Of the nitrogenous fertilizers priority must be given to ammonium nitrate, urea, anhydrous ammonia, and

nitrogen solutions.

The above performance data show that anhydrous ammonia is the most advantageous nitrogenous fertilizer from the point of view of economy. Among the solid nitrogenous fertilisers the best indices are characteristic of urea.

The basic advantage of anhydrous ammonia, as well as other liquid fertilizers is the labour saving at the stages of both manufacturing and application.

Agro-chemical properties of various nitrogenous fertilizers do not differ much.

Our experience shows, that the start-up and operation of urea process involve considerable difficulties at those plants, which are not operated by adequately trained personnel.

4. By now aqueous ammonia (20.5 p.c. N) is rather widely used in the USSR as fertilizer. To overcome the negative effect of low nitrogen content of this product efforts were applied in the field of manufacture and use of nitrogen solutions. Carbamate solutions can be manufactured profitably at the urea plants. A particular attention should be given to the production of liquid complex fertilizers.

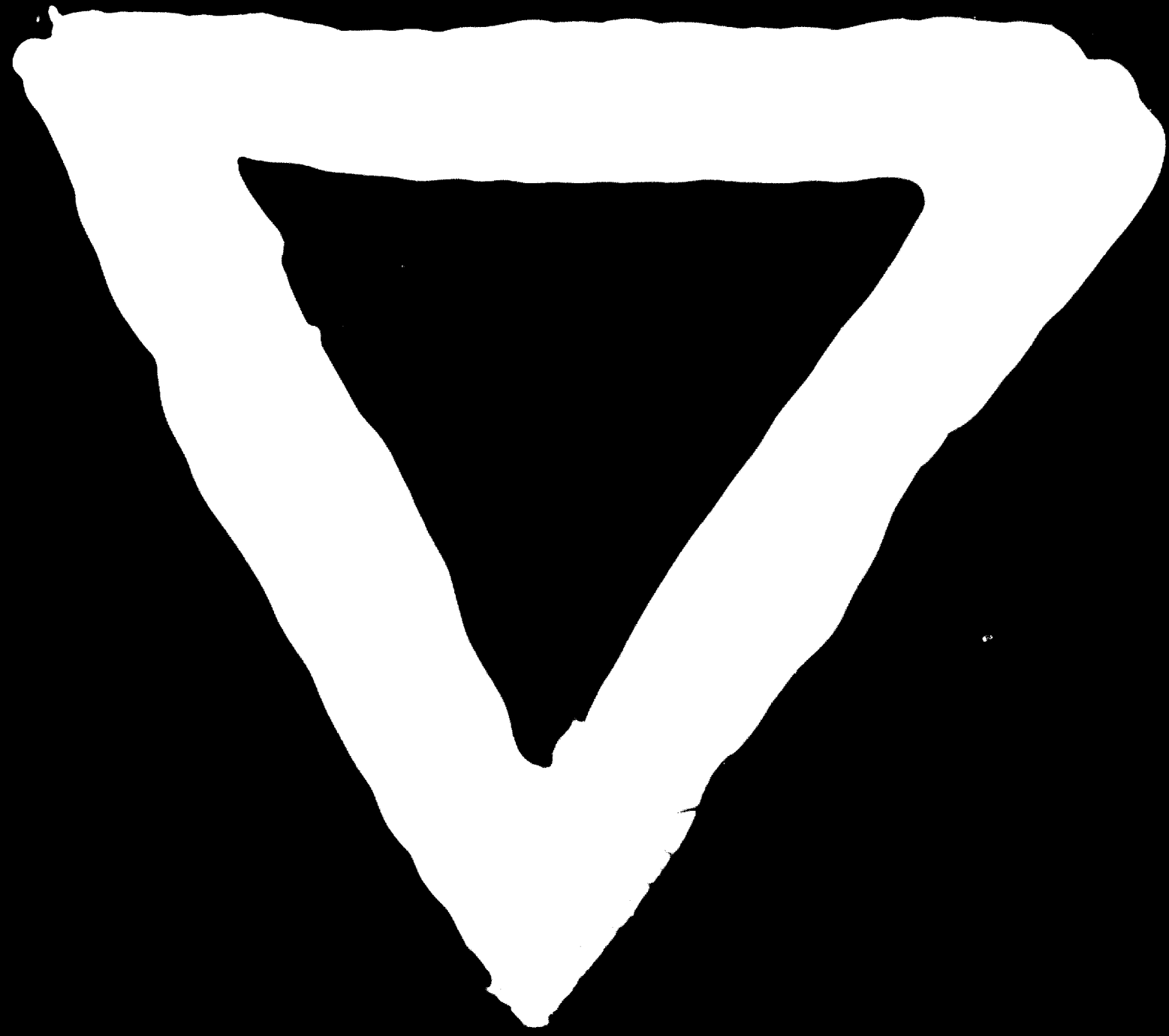
5. Programs of fertilizer supplies meeting the existing and prospective demands can be drawn up by any interested countries.

High efficiency of large-scale ammonia plants suggests the construction of one large-scale plant for two or more countries, if the demand of each of them is lower, than the

capacity of a modern large-scale plant (200,000 to 450,000 ton ammonia in a single stream). The most profitable fertilizer production can be based on natural gas or liquid hydrocarbons (including naphtha).

The decision on the fertilizer production program should be based on the recommendations of agro-chemists, taking into consideration local manufacturing and application conditions.

Also, considered should be the expediency of fertilizer imports from contiguous countries (instead of the establishment of its own production), relying on the additional yield of crops due to the application of fertilizers.



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