50

CENTRAL INTELLIGENCE AGENCY

OFFICE OF RESEARCH AND REPORTS

PROVISIONAL REPORT NO. 5
(CIA/RR PR-5)

THE SYNTHETIC AMMONIA INDUSTRY IN THE USSR

8 October 1951

Note

This document is a working paper. The data and conclusions contained herein do not necessarily represent the final position of ORR and should be regarded as provisional only and subject to revision. Additional data or comment which may be available to the user is solicited. This report contains information available to ORR as of 1 September 1951.

CONTENTS

THE SYNTHETIC AMMONIA INDUSTRY IN THE USSR

Summary

Before the inauguration of the First Five Year Plan in 1928 the USSR produced no synthetic ammonia, all requirements being supplied exclusively by imports. Considerable emphasis has been given to the construction of synthetic ammonia plants, however, and estimated production has increased from about 15,000 to 20,000 metric tons (N) in 1932 to about 550,000 tons (N) in 1951. Satellite production of synthetic ammonia in 1951 is estimated at approximately 430,000 metric tons (N). No synthetic ammonia is imported from non-Bloc countries.

The largest peacetime consumer of synthetic ammonia is the nitrogenous fertilizer industry. Most of the balance is consumed in the manufacture of nitric acid and other chemicals. The supply of synthetic ammonia will not be a factor limiting any course of action by the Soviets, and present productive capacity is capable of supplying requirements in the event of a major war. The average annual Soviet supply during World War II, including Lend-Lease shipments, was about one-third of that now available. The Soviet synthetic ammonia industry is completely self-sufficient and therefore is not vulnerable to economic warfare. Because of the limited number of producing plants in this industry, however, it is vulnerable to strategic bombing.

I. Introduction.

1. Nature and Uses.

Ammonia is a basic industrial chemical, being the cheapest form of combined nitrogen and the raw material used in more than 75 percent of all nitrogenous products. A colorless gas with a characteristic pungent smell, ammonia is produced principally by the high-temperature reaction of pure nitrogen and hydrogen under pressure in the presence of a suitable catalyst. As produced by this process, it is known as synthetic ammonia. Ammonia also is produced as a by-product in the coking of coal, but such ammonia, known as by-product ammonia, is produced in much smaller quantities than the synthetic.

Synthetic ammonia is produced and shipped in two forms, ammonia liquor and liquid anhydrous ammonia. Commercial grades of ammonia liquor usually contain 28 percent ammonia. Liquid anhydrous ammonia is dry ammonia gas compressed to liquid form and shipped at 114 psig 1/ (70°F) in pressure tank cars or cylinders. The anhydrous form is about 99 percent pure and for most purposes in the US has virtually superseded ammonia liquor.

In peacetime, synthetic ammonia is used principally in the manufacture of nitrogenous fertilizers, nitric acid, and industrial explosives. Liquid anhydrous ammonia is the most important commercial refrigerant because of its low cost and high thermodynamic efficiency. Other important uses of liquid anhydrous ammonia are as a low-cost alkali in chemical processes, in the hardening of certain steel alloys, in water purification, and in the manufacture of organic chemicals such as urea, aniline, beta-naphthylamine, hexamethylenetetramine (the base for RDX 2/), etc. In wartime, synthetic ammonia is indispensable because it is required in the manufacture of all nonatomic military explosives.

2. History of the Industry.

a. First Five Year Plan (1928-32).

Before the First Five Year Plan (1928-32) the Soviet Union produced no synthetic ammonia, all requirements being supplied exclusively by imports. The retarded development of the electric power and calcium carbide industries had precluded use of the early arc and cyanamide processes for producing ammonia. The Soviets realized the fundamental economic importance of this industry, however, and started construction at Dzerzhinsk of a Casale-type plant, which went into operation in 1928. Extensive plans were formulated in the 1928-32 period for the development of the nitrogen industry, and considerable foreign aid, both in engineering techniques and in equipment, was enlisted in the construction of plants at Berezniki, Stalinogorsk, Gorlovka, and Stalino. Also during this period, construction probably was started on the Dneprodzerzhinsk plant. Despite feverish activity, however, only two synthetic ammonia plants were in operation at the end of 1932 — namely, the Dzerzhinsk and Berezniki plants — and production totaled from about 15,000 to 20,000 metric tons (N) annually.

1/ Pounds per square inch, gauge pressure.
2/ A powerful military high explosive developed during World War II.

b. Second Five Year Plan (1933-37).

During the Second Five Year Plan (1933-37) the plants at Dneprodzerzhinsk, Stalinogorsk, Gorlovka, and Stalino were put into operation, and construction was begun on plants at Kemerovo and Chirchik. Construction of a plant at Magnitogorsk was planned during this period, but a well-informed source has stated that construction of this plant had not begun in 1937. Thus, at the end of 1937, it is believed that six synthetic ammonia plants were in operation, producing at an annual rate of about 200,000 to 225,000 metric tons (N). Some confusion exists with respect to the status of plants at Magnitogorsk, Lisichansk, Derbent, Sumgait, and Kamensk. During this period, plans for their construction apparently were made, but it is doubted that any actual construction was undertaken.

c. Third Five Year Plan (1938-42).

During the Third Five Year Plan (1938-42), plants at Kemerovo, Chirchik, and probably at Nizhne Tagil were put into operation. Construction of installations at Lisichansk and Kamensk possibly was begun before the German invasion, but it is believed that neither of these plants was producing in significant quantities. Construction of plants using natural gas as the source of hydrogen was planned for Derbent and Sumgait. Some information indicates that these plants were built and put into operation between 1938 and 1940, but their existence has not been confirmed, and it is assumed that they never got past the planning stage. Postwar efforts of the Soviet Purchasing Commission in the US to purchase a complete synthetic ammonia plant which would operate on hydrogen derived from natural gas lend support to this view, as it is unlikely that the Soviets would have been interested in the purchase of a plant of this type if such an installation was already operating in the USSR. As previously mentioned, the plant at Magnitogorsk was not even under construction in 1937, and it is assumed that this plant likewise never got beyond the planning stage. Thus in early 1941, just before the German invasion, there probably were nine plants in operation in the USSR, producing at an annual rate of about 350,000 metric tons (N).

Because of war conditions the plants at Dneprodzerzhinsk, Stalinogorsk, Gorlovka, and Stalino suspended operations in 1941, thereby reducing Soviet synthetic ammonia capacity by about 185,000 metric tons (N), or approximately 53 percent. This capacity was not completely lost, however, since considerable equipment was evacuated from these plants to existing installations farther east. In addition, it is believed that some equipment also may have been evacuated from the plants at Kamensk and Lisichansk.

Production of synthetic ammonia in the USSR during World War II is estimated as follows, the increase from 1942 to 1945 resulting principally from expansion of capacity at the Chirchik and Kemerovo plants:

Estimated Soviet Production of Synthetic Ammonia
1941-45

Year	Thousand Metric Tons (N) Production
1941	200
1942	175
1943	225
1944	250
1945	300

d. Fourth Five Year Plan (1946-50).

Following the expulsion of the German army from Soviet territory, reconstruction of damaged and evacuated plants was begun immediately, and the Fourth Five Year Plan (1946-50) was drawn up. Although as published the Plan made no mention of synthetic ammonia, it probably provided for the restoration of damaged plants; possibly for expansion of the installation at Chirchik; for completion of plants at Lisichansk and Gubakha; and for construction of new plants at Kirovakan, Dzerzhinsk, and Rustavi. The status of plans for reconstruction at Kamensk are unknown.

The over-all plans for the industry during this period probably were too ambitious, and despite the acquisition of dismantled German and Manchurian equipment and the aid of German technologists, it is believed that the goals were only partially realized. Achievements can be summarized briefly. The Stalinogorsk plant, which was not damaged and not completely removed, reportedly resumed operations about the beginning of 1945 and is now in full production. The Gorlovka and Dneprodzerzhinsk plants resumed production on a partial basis in 1946 and early 1947, respectively, and are now believed to be producing at about their prewar rates. A new plant was reportedly projected for early 1949 at Stalino, replacing the one which undoubtedly was destroyed. Some evidence indicates that the plant at Chirchik may have been expanded since 1945. The plant at Kirovakan apparently has not yet been completed but may come into operation in 1951. The Lisichansk plant is believed to have begun production in May or June 1951. The Gubakha plant was last reported as under construction in 1945, and its present status is unknown. It possibly could be in operation, but no information is available. A new synthetic ammonia plant, part of a lactam (nylon) plant, was reportedly

put into operation at Plant No. 96, Dzerzhinsk, about April or May 1949. This plant apparently was constructed with dismantled equipment from the Leuna Works at Merseburg, Germany. Another synthetic ammonia plant has been reported under construction at Rustavi, Georgia SSR. Construction was reported to be proceeding slowly in November 1949, however, and only the foundations of the buildings were completed. Estimating the completion date in the light of postwar construction of other plants of this type, the Rustavi plant probably will not start production before 1953. Production during the period of the Fourth Five Year Plan is estimated as follows, Appendix A presenting the methods used in making these estimates:

Estimated Soviet Production of Synthetic Ammonia
1946-51

Year	Thousand Metric Tons (N) Production
1946	323
1947	368
1948	440
1949	489
1950	534
1951	550

II. Operation.

1. Technology.

The synthetic ammonia process most widely used throughout the world today, including the USSR, is the original Haber-Bosch process with various modifications. Other processes in use are the NEC (Nitrogen Engineering Corporation), Claude, Casale, Fauser, and Mont Cenis. These processes are basically the same as the Haber-Bosch process with various modifications of temperature, pressure, catalysts, method of hydrogen and nitrogen manufacture, etc. 1/ The synthetic arc and cyanamide processes are now outdated. In all of these processes the source of the nitrogen for the ammonia synthesis is generally from an air liquefaction plant, from producer gas, or from the "blow gas" from a water-gas generator. The principal sources of hydrogen for ammonia synthesis are water gas, coke-oven gas, electrolysis of water, electrolysis of brine, and natural gas.

1/ Synthetic ammonia and methanol can be produced in the same type of high-pressure equipment with only minor changes. Consequently, many plants are built with convertible units.

In the USSR the percentage of hydrogen obtained from each source is estimated to be approximately as follows: water gas, 43 percent; coke-oven gas, 41 percent; and electrolysis of water, 16 percent. No ammonia plants in the USSR are known to be operating on hydrogen derived from brine electrolysis or from natural gas. The catalyst used in converting the nitrogen and hydrogen gases to ammonia is, almost without exception, iron promoted by oxides of metals such as aluminum, zirconium or silicon, and potassium.

2. Input Requirements.

For a production of 231,000 metric tons (N) of synthetic ammonia from plants using the water-gas process, input requirements are estimated as follows:

Coke	500,000 Metric Tons
Electricity	800 Million Kilowatt-hours
Direct Labor	5 Million Man-hours (Based on US Production Standards)

For an output of 219,000 metric tons (N) of synthetic ammonia from plants using the coke-oven gas process, input requirements are estimated as follows:

Bituminous Coal, Washed, for the Manufacture of 21.9 Billion Cubic Feet of Hydrogen	3.3 Million Metric Tons 1/
Electricity	750.0 Million Kilowatt-hours
Direct Labor	5.0 Million Man-hours

For a production of 84,000 metric tons (N) of synthetic ammonia, using the water electrolysis process for hydrogen, input requirements amount to the following:

Electricity	1.45 Billion Kilowatt-hours
Direct Labor	1.95 Million Man-hours (Based on US Production Standards)

1/The coke-oven gas from which this hydrogen is extracted is a by-product in the manufacture of coke and therefore does not constitute an additional requirement for coal.

III. Availabilities.

1. Domestic Production.

Soviet production of synthetic ammonia in 1950 is estimated at 534,000 metric tons (N) (range: 450,000 to 550,000), and 1951 production is about 550,000 metric tons (N) (range: 500,000 to 600,000). The following table summarizes the estimated capacity and production of Soviet synthetic ammonia plants:

Estimated Capacity and Production of Soviet Synthetic Ammonia Plants 1951

Location	Plant	Thousand Metric Tons (N) Estimated Capacity	Estimated Production	Percent of Total
South Region				
Dneprodzerzhinsk	Nitrogen Fertilizer Plant	60	50	
Gorlovka	Nitrogen Fertilizer Plant	86	72	
Lisichansk (Verkhne)	Liskhimstroy	N.A. (probably about 50)	16	
Stalino	Nitrating Plant Karpova	9	7	
Subtotal		205	145	27
Central Industrial Region				
Dzerzhinsk	Chemical Plant Kalinin	40	33	
Dzerzhinsk	Chemical Plant Stroy	N.A.	N.A. a/	
Stalinogorsk	Chemical Combine Stalin	107	90	
Subtotal		147	123	22
Urals Region				
Berezniki	Chemical Combine Voroshilov	129	108	
Nizhne Tagil	N.A.	50	42	
Subtotal		179	150	27
West Siberia Region				
Kemerovo	Nitrogen Fertilizer Plant No. 3	57	48	
Subtotal		57	48	9

a/ Probably small.

Estimated Capacity and Production
of Soviet Synthetic Ammonia Plants
1951
(Continued)

Location	Plant	Estimated Capacity (Thousand Metric Tons (N))	Estimated Production (Thousand Metric Tons (N))	Percent of Total
Kazakhstan and Central Asia Region				
Chirchik	Electrochemical Combine Stalin	100	84	
Subtotal		100	84	15
Total		688	550	100

Three new plants are under construction. An installation at Kirovakan, Transcaucasus, with a probable capacity of about 50,000 metric tons (N) a year may begin producing in 1951. A plant of unknown capacity at Rustavi, Transcaucasus, is reportedly in the early stages of construction, while the status of construction of a plant at Gubakha, Urals, is unknown. It is believed that, in the event of a general war, maximum output for 1951 at the most would be about 600,000 tons, or 50,000 tons more than estimated 1951 production. Such an increase probably could be attained by getting the Kirovakan plant into operation more quickly and by intensified production at Lisichansk and the other plants now in operation.

2. External Sources.

a. Satellites.

No information is available on Soviet imports of synthetic ammonia from the Bloc countries. Satellite production of synthetic ammonia in 1951, however, is estimated as follows:

Estimated Satellite Production of Synthetic Ammonia
1951

Country	Thousand Metric Tons (N) Production
East Germany	300
Poland	55
Czechoslovakia	40
Hungary	12
Manchuria	12
Rumania	10
Bulgaria	1
North China	0
Total	430

b. Non-Bloc Countries.

No synthetic ammonia is imported from non-Bloc countries. Western restrictions on shipment of anhydrous ammonia to Soviet Bloc countries probably have little or no effect on the peacetime economies of these countries, but relaxation of controls might permit greater stockpiling of explosives and food for the military forces. The embargo on equipment for the manufacture of anhydrous ammonia, on the other hand, definitely retards the Soviet war potential. Supplies potentially available from countries that might be overrun by the USSR cannot be determined until a study of this industry in Western Europe, the Middle East, and Southeast Asia has been made.

3. Stockpiles.

High-pressure tankage is required for storage of synthetic ammonia, which precludes building up any large reserves of this chemical. Outside of a relatively small quantity in the industrial pipeline, it can safely be assumed that there are no reserves of synthetic ammonia in the Soviet Bloc.

4. Substitutes.

There are no substitutes for synthetic ammonia. The ammonia produced as a by-product in the coking of coal cannot be regarded as a substitute for synthetic ammonia, because it is produced in relatively small volume and in the form of a weak solution with water rather than in the gaseous form of the synthetic product.

IV. Requirements.

1. Civilian.

The principal Soviet end uses of synthetic ammonia are estimated as follows:

Estimated Principal Soviet End Uses of Synthetic Ammonia
1950

Thousand Metric Tons (N)

End Use	Requirements	Range of Variation of Estimate	Percent of Total
Fertilizers (excluding Nitric Acid)	235	200 to 270	44
Nitric Acid	177	157 to 197	33
Miscellaneous a/	122	100 to 144	23
Total	534	457 to 611	100

a/ The most important miscellaneous uses are mentioned below.

The largest consumer of synthetic ammonia during peacetime is the nitrogenous fertilizer industry. The 1950 production of nitrogenous fertilizers in the USSR is estimated to have been about 1.42 million metric tons, of which about 249,000 tons were produced from coke by-product ammonia in the form of ammonium sulphate. The remaining 1.17 million tons of nitrogenous fertilizers would have required about 235,000 tons of nitrogen in the form of synthetic ammonia, exclusive of that synthetic ammonia oxidized to nitric acid for the manufacture of fertilizers.

The next largest peacetime use for synthetic ammonia is in the manufacture of nitric acid, which is used in the production of fertilizers, explosives, plastics, insecticides, inorganic nitrates (silver, copper, sodium), dye intermediates, and many other essential products. The 1950 production of nitric acid in the Soviet Union is estimated to have been about 715,000 metric tons, which would have required approximately 177,000 tons of ammonia nitrogen. The assumption here is that all nitric acid in the USSR is produced by the oxidation of ammonia and none from saltpeter.

The remaining 122,000 tons of synthetic ammonia, or 23 percent of total production, undoubtedly were consumed in the manufacture of such chemicals as urea, soda ash, cyanides, ammonium chloride, ammonium carbonate and bicarbonate, and ammonium perchlorate; in the manufacture of nylon-type

fibers and plastics and of paper; in ammonia refrigeration units; in water treatment; in the rubber industry (to preserve latex); in metallurgy (case hardening and bright annealing); and in the petroleum industry (to prevent corrosion in tank storage of sour crudes, to treat lube oil, and to make wax and gasoline).

2. Military.

No information is available concerning Soviet military requirements for synthetic ammonia, either for maintenance of stand-by forces, for limited campaigns, or for a major war. Using the availability of raw materials as a basis, it has been possible, however, to make a rough estimate of the Soviet maximum potential for the production of explosives. Synthetic ammonia requirements to meet this maximum explosives production program are estimated at about 250,000 metric tons (N). After allocation of this amount for explosives production, an estimated 300,000 tons will be available in 1951 to meet industrial, fertilizer, and indirect military requirements. It is believed, therefore, that sufficient ammonia will be available in the USSR to sustain a major war.

3. Exports.

No information is available concerning Soviet export of synthetic ammonia. Since this product must be shipped in heavy pressure containers, it is unlikely that the Soviets carry on any foreign trade in this commodity.

V. Capabilities, Vulnerabilities, and Intentions.

1. Capabilities.

The supply of synthetic ammonia available to Soviet Bloc countries in 1951 is estimated at from 900,000 to 1.1 million metric tons (N). The supply of this essential chemical, therefore, will not be a factor limiting any course of action by the Soviets, and present productive capacity is capable of supplying requirements in a long and vigorous war. The average annual Soviet supply during World War II, including Lend-Lease shipments, was about one-third of that now available.

2. Vulnerabilities.

The Soviet synthetic ammonia industry is completely self-sufficient and, therefore, is not vulnerable to economic warfare. This does not mean, however, that export controls on products derived from ammonia or on plant equipment should be relaxed, since this would allow more rapid stockpiling and the expansion of production capacity.

Because of the limited number of producing plants, this industry is vulnerable to strategic bombing, but, on the other hand, the geographic locations of at least three large plants are such that this vulnerability might be limited. No studies have been made of stockpiles of explosives, ammunition, and other products derived from ammonia, so that no estimates can now be made regarding the length of time before restriction of supply would affect the Soviet war potential.

3. Intentions.

Operations in the synthetic ammonia industry which might indicate Soviet preparations for war are (a) an increase in the production of concentrated nitric acid, which would be necessary for a large explosives program; (b) a decrease in the production of ammonium nitrate; (c) a noticeable or unusual shortage of ammonium nitrate fertilizer; (d) cessation or restriction of exports of nitrogen fertilizers; and (e) allocation of nitric acid to explosives plants rather than to fertilizer plants.

APPENDIX A

METHOD OF COMPUTING SOVIET PRODUCTION OF SYNTHETIC AMMONIA

Estimates of Soviet production of synthetic ammonia were computed on the following bases. A study of the eight plants in operation in 1940 (Chirchik did not start operations until 6 November 1940 and thus did not contribute to the annual total) revealed that 1940 production was about 340,000 metric tons (N). Using this figure as a base, production in 1946, 1947, and 1948 was calculated from the information that the output in these years was 95 percent, 108 percent, and 130 percent (planned), respectively, of 1940 production.

The maximum annual capacity of the nine plants believed to be operating in 1949 is estimated at 638,000 metric tons (N). Part of this capacity undoubtedly is assigned to the production of methanol, but available information is not sufficient to make a firm estimate of this percentage. In the US, about 20 to 30 percent of the synthetic ammonia capacity is devoted to methanol production. Because of the relatively greater USSR production of methanol from wood distillation and the relatively lower development of their solvents and plastics industries, it is estimated that only about 10 percent of the USSR synthetic ammonia plant capacity is devoted to the production of synthetic methanol. Production of synthetic methanol by ammonia plants thus would amount to approximately 70,000 metric tons in 1949, reducing the total USSR capacity for synthetic ammonia production to 574,560 tons (N) in 1949. Therefore, assuming that the Soviets have now acquired sufficient skill to operate these plants within practical limits of their designed capacities and that the industry as a whole has attained an operating efficiency of 85 percent of installed capacity, Soviet production of synthetic ammonia in 1949 would have amounted to 489,000 metric tons (N), an increase of 11 percent over the estimated 1948 production of 440,000 tons.

The estimate of 1950 production was based on the assumption that an additional 45,000 metric tons of nitrogen would be available from increased operating efficiency of the existing plants, particularly of the rehabilitated plants at Dneprodzerzhinsk, Gorlovka, and Stalino; from the new plants at Dzerzhinsk; and possibly from the new plant at Lisichansk (Verkhne). This would bring the 1950 production up to 534,000 metric tons (N), an increase of 9 percent over 1949 production and 57 percent over 1940 production. No specific information concerning the 1950 plan for synthetic ammonia production has been released by the Soviet Union. Indirect evidence is available, however, from the official statement that "the law provides for an increase in the production of mineral fertilizers to guarantee, by 1950, 1.8 times as much nitrogenous fertilizer as was produced before the war." Because of Soviet preparations for war and the consequent increase in the manufacture of explosives in 1940, the peak year for the production of nitrogen fertilizers

probably was either 1938 or 1939. Multiplying the estimated 1939 synthetic ammonia production of 300,000 metric tons (N) by 1.8 gives a 1950 planned figure of 540,000 tons, which closely checks with the figure of 534,000 tons estimated above.

Production of synthetic ammonia in the Soviet Union in 1951 probably will reach 550,000 metric tons (N), an increase of 16,000 tons, or about 3 percent, over the estimated 1950 production. This increase will come almost entirely from the plant at Lisichansk (Verkhne), believed to have been completed in late 1950 or early 1951.