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A NEW CONCEPTION OF AN AMMONIA PRODUCTION UNIT WITH A LOW ENERGY CONSUMPTION

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RESUME

La réduction de la consommation de gaz naturel continue à être l'un des principaux problèmes de la production d'ammoniac. Les prix du fuel changent rapidement en Russie. Le prix de 1000 m^3 de gaz naturel a atteint $ 16-18 en 1993 et continue à augmenter. Le prix stable probable du gaz naturel sur le marché intérieur russe atteindra $ 45 par 1000 m^3 prochainement. Les estimations des perspectives de production d'ammoniac et d'engrais à base d'ammoniac montrent qu'avec ce prix du gaz naturel, seules les unités d'engrais azotés utilisant de l'ammoniac obtenu avec une consommation d'énergie inférieure à 7 Gcal par tonne resteront économiques.

Ainsi, le problème de la construction d'une unité d'ammoniac économe d'énergie basée sur de nouvelles réalisations de GIAP dans le domaine de la technologie, de l'équipement et des catalyseurs est très urgente. En développant le concept d'une nouvelle unité d'ammoniac, nous avons considéré les différents aspects suivants du problème :

Aspect thermodynamique : Il est clair d'après les considérations thermodynamiques que la quantité d'énergie primaire introduite dans l'unité doit être limitée car les processus de récupération sont inévitablement liés à la croissance de l'entropie. Il est assez difficile d'éviter des pertes de produit dans le procédé qui ne dépassent pas 1 à 2 % même dans les unités d'ammoniac anciennes. Aussi, est-il surtout nécessaire de réduire la génération de vapeur en la limitant aux besoins inévitables du procédé et à la génération d'énergie mécanique utilisée pour la compression et les pertes hydrauliques. La récupération inévitable de chaleur doit être effectuée aux niveaux les plus élevés de température. C'est l'essence de l'approche que nous avons utilisée en développant le concept de la nouvelle unité d'ammoniac.

Aspect environnement : On s'attend à ce que les limites imposées au fuel primaire utilisé et à la génération de vapeur influent sur la quantité d'effluents liquides et les émissions gazeuses. Nous avons procédé à partir de la nécessité de réduire les émissions de gaz nuisible de trois à quatre fois et d'exclure le rejet des condensats du procédé presque complètement.

Fiabilité et sécurité : Ces problèmes sont résolus en diminuant la part des équipements qui fonctionnent à la température la plus élevée des parois, réduisant la pression de synthèse de l'ammoniac jusqu'à 80 bars, excluant les turbines à vapeur de la compression de gaz de synthèse. L'unité n'utilise pas de solvants toxiques.

Système de contrôle : Un système de contrôle décentralisé à base de micro-processeur a été adopté. Les sous-systèmes de groupe fonctionnel sont formés, qui fournissent un contrôle fiable et simple, ainsi que la possibilité de concevoir et de modifier le système de contrôle par les ingénieurs de procédés. Les ordinateurs du système de contrôle sont fabriqués et fournis sous licence de Honeywell.

Investissement : La rentabilité de la production d'ammoniac dans le nouvel atelier est fournie par le fait que malgré une plus faible consommation d'énergie, les investissements n'augmentent pas par rapport aux unités de la génération précédente. Ceci est réalisé en utilisant des compresseurs et de l'équipement de synthèse d'ammoniac meilleur marché, fonctionnant à 80 bars, des réacteurs catalytiques à flux radial et un four primaire deux fois plus petit, des catalyseurs conventionnels ou modifiés.

Approches techniques : Le procédé GIAP pour la production d'ammoniac à une pression de 80 bars, repose sur le reforming combiné de type "Tandem" de gaz naturel, employant des réacteurs à flux radial à tous les stades de procédé, y compris le reforming secondaire, une synthèse d'ammoniac en cascade à une pression de 80 bars, et en utilisant de nouveaux catalyseurs fabriqués sur la base des procédés GIAP.

Consommation d'énergie de base pour les unités d'ammoniac d'après le procédé GIAP : Le nouveau concept d'unité d'ammoniac permet d'obtenir de l'ammoniac liquide avec une consommation d'énergie de 28,01 GJ/t et une consommation de gaz naturel (valeur calorifique 8807 kcal/m^3) de 708,1 m^3/t.

Nous pensons que ce nouveau concept d'unité d'ammoniac intéressera un grand nombre de producteurs d'engrais dans différentes régions du monde.

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Cutting the natural gas consumption remains, as before, one of the main problems in ammonia production. The quantity of primary fuel spent for 1 t of product affects both the cost of ammonia and the nitrogen fertilizers produced from it. Quick changes of fuel prices are now taking place in Russia. The natural gas price for 1000 m^3 was 52 roubles in 1991, 1,100 in 1992, 18,000 in 1993, and 40,000 in April 1994. So, the price for 1000 m^3 of natural gas reached $ 15 in 1993 and $ 22 in the beginning of 1994 and continues to increase. The probable stable price of natural gas in the internal market of Russia will be in the near future about $ 45 per 1000 m^3. The cost estimates of the production of ammonia and fertilizers based at such natural gas prices show that only those nitrogen fertilizer production plants will be economical and competitive in the world market if ammonia is produced with energy consumption at not more than 7 Gcal/t. The investments into construction of such units shall not in this case be more than those of the previous generation.

In Russia, the majority of the ammonia units were built in the 1970's with the capacity of 1360 t/day and the energy consumption of 9.2 to 10.2 Gcal/t. In Russia and the countries of C.I.S. 44 units of this type have been constructed of which 42 are in operation. GIAP has developed several versions of modernization of these units and has analysed offers of world renown engineering companies. The results of these analysis evoke no optimism because at admissible investments the decrease of energy consumption does not exceed 10%. In such a way, even modernized units, particularly those which are far from markets of ammonia and fertilizers, will prove to be beyond the production profitability.

This brief analysis indicates that the problem of development of an ammonia unit with a low energy consumption is very urgent for Russia. At the IFA Congress in Moscow in September 1991, we reported that recently GIAP has studied new processes and equipment for processing fuel into process gas for production of ammonia, methanol, hydrogen, carbon monoxide, carbon dioxide, and other products. These new achievements of GIAP in the field of technology, equipment, and catalysts have created a scientific and technical basis for development of such a unit.

In development of the conception of a new ammonia unit, we took into consideration the aspects of the problem as follows.

Thermodynamic aspect

It is evident that there are, in principle, two approaches. The first one does not set strict limitations to the quantity of primary energy introduced in an ammonia unit. In this case, the main consideration is given to the search of refined methods of subsequent energy recovery. Such an approach is the basis of the conception of the above ammonia units of the 1970's in which a huge quantity of energetic steam (6.5 t/t NH_3) and mechanical energy (about 0.9 to 1.0 MW/t NH_3) is produced. The same ways are also used in case of modernization of these units. It is clear from the thermodynamic considerations that the quantity of primary energy introduced in a unit shall be limited because recovery processes are inevitably connected with a growth of entropy. It is very difficult to avoid technological losses of matter which do not exceed 1 to 2% even in old ammonia units.

Hence, first of all it is necessary to cut steam production by limiting oneself only to inevitable process needs as well as the production of mechanical energy used for compression of process streams and for hydraulic losses. In this case, the inevitable heat recovery shall be carried out at the highest temperature level. This is the essence of the second approach which we used in development of the conception of the new ammonia unit.

Ecological aspect

It may be supposed that the limitations to the primary fuel used and the steam production will tell upon the quantity of liquid and gaseous effluents to environment. We proceeded from the necessity to cut harmful gaseous effluents 3 to 4 times and to exclude nearly completely the effluents of process condensate.

Reliability and safety

It shall be taken into consideration that the reliability and safety of the unit increase if one can diminish the portion of equipment operating at the highest temperature and pressure, simplify compressors, exclude the high-pressure steam lines and the turbines using high-pressure steam. The control system shall ensure a reliable functioning of all the elements of the unit, maintain subsystems for diagnostics of the equipment status, process and display their information.

Designs

We indicated above that the thermodynamic considerations assumed as a basis of the conception of energy saving may be realized by utilization of the newest developments of GIAP in the field of technology, equipment, and catalysts. In conformity with this conception of the ammonia unit, we have taken the designs as follows **(Figure 1)**.

Natural gas desulphuration

Depending on the sulphur compounds content of natural gas, zeolite purification (zeolites of NaX - 13X type) or purification by catalytic hydrogenation followed by H_2S absorption with zinc oxide is used. In case of the two-stage catalytic purification, AKM hydrogenation catalyst and GIAP-10 absorbent developed by GIAP are used. A peculiarity of the technology is that to carry out the process in both cases GIAP-designed radial reactors are used which have a low pressure loss (0.03 bar) and allow the degree of utilization of an adsorbent to be increased by 5% and the weight of equipment to be decreased by 72% compared to the units of the previous generation. The dimensions and weight of the equipment for a unit with the capacity of 1500 t/day of ammonia are given in **Table 1**.

Combined natural gas reforming

The combined reforming system in conformity with the energy saving conception adopted assures the energy recovery of the fuel introduced in the unit at the highest temperature level. The combined natural gas reforming includes a primary reformer in the combination with a shell-and-tube reactor of recovery reforming and a secondary reformer. The gas stream downstream of desulphuration is divided into two parts in the ratio of 0.46/0.54 and is fed parallel into the primary reformer and the shell-and-tube reactor. Into the shell side of the shell-and-tube reactor, the gas from the secondary reformer is fed about 63% of heat of which is used to carry out the endothermic reaction of steam reforming of methane. This allows the steam production in a steam boiler to be diminished 2.7 times, this boiler operating in the temperature range of 340 to 600°C.

The reliability of the steam boiler increases substantially because the gas inlet temperature falls from 1000 to 600°C. Because of lowering the primary reformer load and decrease of the total steam production, the fuel gas consumption is equal only 130 m^3/t of ammonia vs. 420 to 440 m^3 in a usual unit. Respectively, the emission of flue gas to atmosphere diminishes more than 3 times compared to a usual ammonia unit. Heat losses and emissions of nitrogen and sulphur oxides decrease at the same proportion. The characteristics of emissions are given in **Table 2**.

The combined system of reforming allows a flexible accomodation to conditions on a client's site, a change of the correlation between the consumption of natural gas and power, the steam export and import, the total energy consumption per tonne of ammonia, the heat losses, and the effluents to environment being kept at minimum. The combined system described here does not need an air separation unit. If there is such a unit on a client's site, one may exclude the primary reformer from the process flowsheet or decrease its dimensions. In the latter case, we refer to the classic reforming system "Tandem" on which we reported at the IFA Congress in Moscow in 1991. The equipment of the combined reforming system is adapted to the total unit conception.

Figure 1: Ammonia process flow sheet

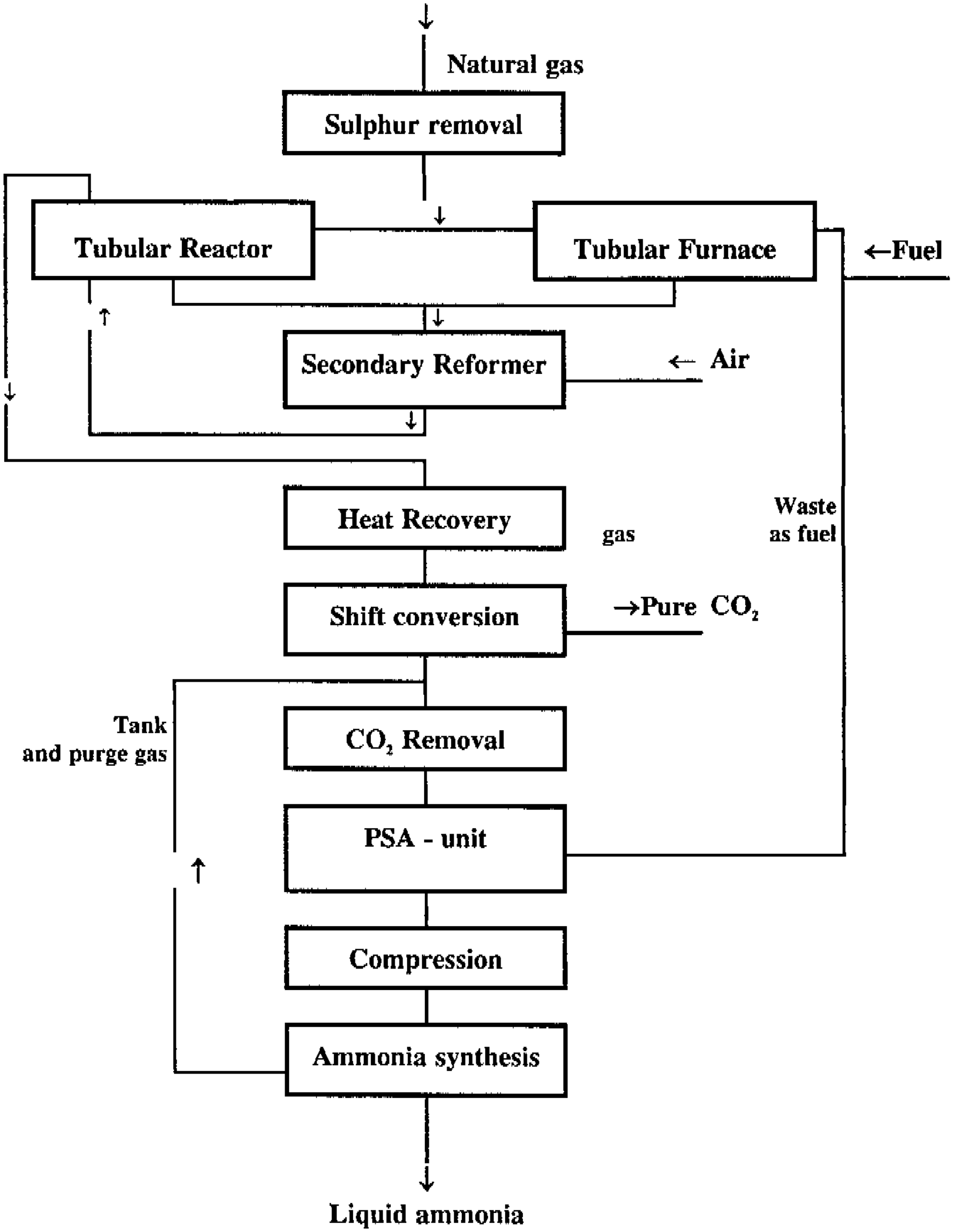

Table 1: List of the main technological equipment 1500 t/day

No.	Description	Characteristic	Quantity	Weight, kg
104	Reactor of hydrogenation of sulphur compounds	$\varnothing=1800$ mm, $H=9450$ mm, $V_{cat}=8.5\ m^3$	1	16000
105	Hydrogen sulphide absorption reactor	$\varnothing=2600$ mm, $H=10300$ mm, $V_{cat}=21\ m^3$	1	31000
107	Primary reformer	9700x41000x22500 mm, $V_{cat}=17.8\ m^3$	1	
110	Secondary reformer	$\varnothing=4000$ mm, $H=17410$ mm, $V_{cat}=34\ m^3$	1	122800
111	Primary reforming shell-and-tube reactor	$\varnothing=3600$ mm, $H=23000$ mm, $V_{cat}=14\ m^3$	2	201000
114	Shift conversion reactor, medium-temperature	$\varnothing=3800$ mm, $H=18000$ mm, $V_{cat}=90\ m^3$	1	81000
117	Shift conversion reactor, low-temperature	$\varnothing=3800$ mm, $H=22000$ mm, $V_{cat}=126\ m^3$	1	100000
150	Condensate purification scrubber	$\varnothing=1800$ mm, $H=15000$ mm	1	35000
301	Absorber	$\varnothing=3800$ mm, $H=30250$ mm	1	152000
302	Regenerator	$\varnothing=3600$ mm, $H=30000$ mm	1	116000
303/1	Desorber-1	$\varnothing=3600$ mm, $H=18800$ mm	1	34500
303/2	Desorber-2	$\varnothing=3600$ mm, $H=20000$ mm	1	34000
501	PSA Adsorber	$\varnothing=2800$ mm, $H=11500$ mm, $V_{cat}=45\ m^3$	4	40000
601	Ammonia Converter	$\varnothing=3100$ mm, $H=21000$ mm, $V_{cat}=75\ m^3$	3	283000

Table 2: Characteristic of process gas emission to atmosphere

Ejection place	Quantity of sources	Ejection flowrate m^3/hour	Periodicity	Temperature, ^0C	Composition	Quantity of harmful components ejected, g/s
Natural gas preheater	1	12944	permanently	200	CO_2 6.5%, N_2 70.7%, O_2 7.5%, H_2O 15.3%, $(NO+NO_2)$ 190 mg/m^3, CO 80 mg/m^3, SO_2 8.9 mg/m^3	$(NO+NO_2)$ 0.686, CO 0.289, SO_2 0.032
Primary reformer	1	102000	permanently	120	CO_2 6.3%, N_2 70.9%, O_2 2.5%, H_2O 20.3%, $(NO+NO_2)$ 80 mg/m^3, CO 60 mg/m^3, SO_2 7.3 mg/m^3	$(NO+NO_2)$ 2.26, CO 1.7, SO_2 0.207
Ammonia converter start-up preheater	1	60000	periodically at unit start-up	200	CO_2 6.5%, N_2 70.7%, O_2 7.5%, H_2O 15.3%, $(NO+NO_2)$ 190 mg/m^3, CO 80 mg/m^3, SO_2 8.9 mg/m^3	$(NO+NO_2)$ 3.16, CO 1.33, SO_2 0.148

The primary reformer has no auxiliary boiler. It uses tubes with an enlarged internal diameter of "Manurite"-type alloy. The GIAP-designed primary reformer (shell-and-tube reactor) uses seamless tubes of chromium/nickel steel with the internal diameter of 89 mm and the wall thickness of 7 mm. The pressure difference on the tube wall is only 1 to 2 bar. For secondary reforming, a radial reactor is used which has been designed at GIAP and has the pressure loss of about 0.25 bar and low heat losses. The total pressure loss of the combined reforming system decreases by about 2 to 3 atm compared to usual units. As a result, the total pressure in the reforming system may be lowered. This favours an increase of the methane conversion and augments the operation reliability of the whole equipment including the air compressor. The energy consumption by the air compressor diminishes. The primary reforming uses GIAP-16 K-15 catalyst, the secondary one uses GIAP-3-6H K-15 catalyst.

Shift conversion

The two-stage shift conversion is carried out in GIAP-designed radial reactors which ensure a constant low pressure loss (0.07 bar for the medium-temperature stage and 0.05 bar for the low-temperature one), a prolonged catalyst service life at the conversion of 0.98. The medium-temperature stage uses CTK-1M-5 catalyst developed at GIAP and operating at the space velocity of 2246 per hour, the low-temperature one uses GIAP catalysts HTK-4 and K-CO operating at the space velocity of 1753 per hour. The carbon monoxide concentration downstream of shift conversion does not exceed 0.28% at the end of the catalyst service life.

Carbon dioxide removal from gas by methyl diethanolamine

In the process flowsheet considered here, carbon dioxide is removed from the gas by 52% aqueous solution of methyl diethanolamine to meet the needs of the clients who have urea plants. The carbon dioxide content of the purified gas is 0.05%. The removal unit allows practically 100% of carbon dioxide to be removed from the gas in two streams. The first stream which makes up 40% of the total quantity contains 99.5% of carbon dioxide at the pressure of 1.4 bar. The second stream consists of pure carbon dioxide at the pressure of 1.2 bar. The quantity of carbon dioxide obtained is 1.23 t/t of ammonia. The process flowsheet includes three steps of absorbent regeneration of which only in the third step the solvent heating up to 115°C is used. About 26% of circulating solvent is subjected to fine regeneration.

This solvent is sprayed into the absorber top. In the first two steps, solvent is regenerated by consecutive pressure release down to 1.2 bar. In such a way, the heat requirement for regeneration of solvent is cut and a high degree of gas purification is achieved. The power requirement for solvent circulation is diminished by introduction of a pump/motor/turbine unit which recovers the energy of saturated solution. The consumption of heat in this flowsheet is 0.674 Gcal, that of power is 62 kWh per 1000 m^3 of carbon dioxide. Owing to the fact that the solvent is practically completely non-corrosive, the whole equipment of the purification unit is made of carbon steel, which substantially affects its cost. In the 1st and 2nd steps of the desorbers, GIAP-H3 metallic packing is used because its effectiveness is about 15% higher than that of Pall rings.

If there is no necessity to extract the whole carbon dioxide in the pure state, a unit using as a solvent dimethyl ethers of polyethylene glycol may be integrated into the process flowsheet of an ammonia unit. The "Highsolv" technology based on utilization of mixtures of polyethylene glycol ethers has been developed by GIAP together with Toho (Japan). Peculiarities of this technology were reported at the IFA Congress in Moscow.

Obtaining pure hydrogen/nitrogen mixture

Pure hydrogen/nitrogen mixture suitable for ammonia synthesis is prepared in a PSA unit. Taking into account the general conception of the ammonia unit, we have integrated this PSA unit into the process flowsheet to achieve the aims as follows:

1. To avoid obtaining low-potential heat and hydrogen consumptions while methanation.
2. To obtain pure hydrogen/nitrogen mixture having low pressure, minimum circulation and a negligible stream of tank and purge gases in the ammonia synthesis loop.
3. To have hydrogen losses and equipment cost not greater than those in ammonia units using methanation.

In order to have minimum hydrogen losses, we sought to obtain the concentrations of methane, carbon monoxide, and carbon dioxide in the gas stream upstream of the PSA unit as small as possible. The combined reforming system allows only the stoichiometric quantity of air to be used and the quantity of argon introduced to be reduced to minimum. In such a way, we could achieve the hydrogen losses in obtaining pure hydrogen/nitrogen mixture equal to about 105 m^3/t NH_3 while in usual units these losses make up 137 m^3/t NH_3.

The investments into the PSA unit are compensated by the absence of the expenses for the methanation system together with the systems of heat recovery, cooling, and gas drying as well as for a unit of hydrogen separation from purge gas. The expenses for equipment and communications in the ammonia synthesis loop and for the ammonia compressor are also cut.

The purified gas for ammonia synthesis contains about 0.14% of argon and only traces of methane, water, carbon monoxide, and carbon dioxide. The waste gas from the PSA unit in the quantity of 169.3 m^3/t NH_3 is burned in the primary reformer burners.

Ammonia synthesis

In ammonia units of the previous generation, ammonia synthesis is carried out at the pressure of 280 to 330 bar. To compress the synthesis gas fed into the synthesis loop, a powerful 4-stage compressor is required with the nominal power of 32 MW for a unit producing 1360 t NH_3/day. Its turbine consumes steam with the pressure of I00 bar and temperature of 482°C at the rate of 350 to 370 t/hour. This turbine produces and the compressor consumes the greatest quantity of mechanical energy.

The energy losses only in condensation of exhaust steam make up 0.35 to 0.4 Gcal/t NH_3. To cut the production of mechanical energy and steam in the limits of the conception of energy saving and decrease of investments, we used in the new ammonia unit a "cascade" ammonia synthesis at the pressure of 72 to 80 bar. The synthesis loop contains three identical blocks consisting of a reactor, a boiler and an economizer for production of steam, recovery heat exchangers, condensers, and a liquid ammonia separator. Ammonia is condensed at the temperature of -10 and -27°C. Such an arrangement of the synthesis loop allows the results to be achieved as follows:

- the synthesis-gas compressor power to be decreased down to 8.7 MW (the synthesis loop capacity is 1520 t/day of ammonia);
- a simple and inexpensive single-body two-stage synthesis-gas compressor with electric motor drive to be used;

- the circulating factor to be decreased down to 2.2;
- to obtain the ammonia concentration at the ammonia converter outlet equal to 11.7 to 12.7% and the ammonia concentration increment of 9 to 11%;
- the cost of the equipment and piping to be cut;
- an iron promoted catalyst to be used;
- the pressure loss to be diminished.

When ammonia synthesis is carried out at a low pressure, it is very important to achieve a low circulation and a low pressure loss in the synthesis loop. However, while decreasing the pressure the degree of compression of circulation gas in the recycle compressor increases. This negative effect in the cascade synthesis flowsheet is compensated by a low gas circulation and a low pressure loss of the equipment whose design and dimensions shall be properly selected.

Particularly, to carry out ammonia synthesis at the pressure of 78 bar, highly effective radial/countercurrent reactors are used which are designed by GIAP, have the pressure loss equal to 1.5 to 2 bar, and use an active iron catalyst prepared according to the GIAP technology. In these conditions, the reactors assure high conversions. The complete system of designs in the synthesis loop allowed a recycle compressor to be used with the power consumption of 2.050 MW. For a usual synthesis loop with 80 bar, a 9 to 10 MW recycle compressor would be required.

Tank and purge gases are recycled. After ammonia removal from them, they are delivered to the PSA unit. For separation of ammonia from purge gas, an adsorption unit is used from which ammonia returns to the synthesis loop. In such a way, aqua ammonia is not obtained in the unit, and the gas containing ammonia is not used for combustion. This excludes losses of hydrogen and nitrogen practically completely as well as favours a decrease in formation and ejection of NO_x.

Steam formation and distribution system

In this system, steam is obtained with the pressure of 40 bar and the temperature of 370 to 380°C for the process and for the air compressor turbine. Two steam drums are provided for. In one of them, steam is collected which is obtained in the ammonia synthesis loop from purified process condensate into which feed water is added. In the second steam drum, steam is collected which is obtained in the boilers of the reforming units and the shift conversion area from boiler feed water. Saturated steam is superheated in the steam superheater of the primary reformer up to 370 to 380°C and is delivered into the steam turbine of the air compressor and into the header. Boiler feed water is preheated upstream of deaeration at the expense of the heat of the gas downstream of the low-temperature shift conversion. Deaerated water (107 t/hour) is delivered to the steam formation system by two pumps with electric motor drives.

Process condensate formed while gas cooling and the components dissolved in it are completely used in the unit. Condensate is preheated and subjected to purification with steam fed to the process in a packed scrubber. The steam leaving the scrubber together with desorbed impurities is mixed with natural gas and is fed to the primary reforming. The steam/carbon ratio is kept equal to 2.9 to 3.15. The purified condensate (about 1 t/t NH_3) is delivered to the steam production system in the synthesis loop.

Control system

In the last years, the developments in the field of measuring transducers, actuators, and computer engineering facilities have achieved good indices in the accuracy of measurements and regulation, reliability, longevity, and repairability, which gives the possibility to substantially enlarge the functions of the Automated Process Control System.

This allows to pass from the control by the process variable value and the situation estimation level by the operator and shift engineer to that by the current value of cost price of the ammonia produced.

Such a control allows subjectivism in the decisions taken to be excluded and, as a result, the unit operation effectiveness to be raised.

This is reached by the determination of the current possibilities of the unit (after each change in the preset limits of the status of any process stage) in the productivity at the minimum processing cost. It includes the continuous estimation of the hydraulic, thermal, and chemical (e.g. catalyst activity) status of the process stages, optimization of the productivity of compressors taking into account the environment temperature and the gas composition as well as keeping the optimum hydrogen/nitrogen ratio, optimization of the purge gas quantity in the ammonia synthesis loop, and others. The solution of the above tasks is achieved by the influence upon the functional-group subsystems which control the stage.

The same system contains a possibility of principle for organization of the start-up/shut-down operations, which also substantially affects the process economics.

The available experience of operation of only a part of the designs proposed at different units confirms the assurance of the stable unit operation and obtaining the increase of its capacity by 5 to 6%.

Basic indices of energy consumption of ammonia units according to GIAP technology

Table 3 shows how the trend of decrease of the energy consumption per tonne of ammonia is dependent on the synthesis pressure. It is seen that the least energy consumption is characteristic for a unit with the synthesis pressure of 80 bar in which the least production of mechanical energy (about 0.66 MW per tonne of ammonia) is achieved.

Table 3: Basic Indices of Consumption of Rawstuff, Energy, and Materials for Ammonia Units According to GIAP Technology per 1 tonne NH_3

Pressure in synthesis loop, bar	320	140*	80
Natural gas, m^{3**}	794.7	718.4	708.1
Oxygen, m^3	0	147	0
Power, kWh	160.1	70.1	481.5
Feed water, m^3	0.709	2.41	0.73
Cooling water, m^3	207.2	195	80.6
Total energy consumption, GJ	30.1	28.8	28.01

Note: * the technology has been developed together with INS, 24-100 Pulawy, Poland
** the calorific value is 8807 kcal/m^3

Investments

The profitability of ammonia production in the new unit is assured by the fact that in spite of decrease of the power consumption, the investment does not increase compared to units of the previous generation. This is achieved because one uses cheaper compressors and equipment for ammonia synthesis for the pressure of 80 bar, radial catalytic reactors, a primary reformer decreased by a half, a simplified and cheaper steam production and consumption system. The calculations in the prices of November 1993* have shown that the investment into construction of the new unit in Russia are by 14% less compared to that into construction of an AM-80 ammonia unit designed by GIAP in the 1980's. Upon estimates of power and material expenses at market prices of West Europe, a saving of about 15% has been obtained. The period of repayment (4.6 to 6.7 years) at the 15% deposit rate on the capital invested is in the limits of the economic expediency of construction of the new unit in Russia.

We believe that the new conception of the ammonia unit corresponds to the expected level of technologies for ammonia production in 1995 to 2000 and will be of interest for a great number of producers of fertilizers in different regions of the world.

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* Exchange rate: December 1993, 1250 roubles per US$