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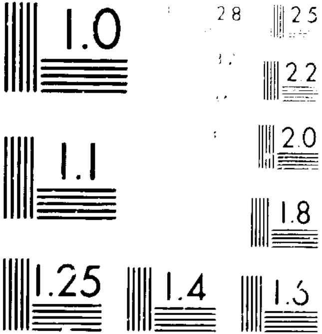
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THE VIABILITY OF 200-300 MT/D NATURAL GAS BASED AMMONIA PLANT*

by

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Abstract

This paper presents the experiences of CNCCC in design and construction of 200-300 MTPD natural gas (or refinery off gas) based ammonia plant. The features of these ammonia plants are discussed in detail. Due to deliberate consideration in design of waste heat utilization, the energy consumption for this type of ammonia plants is close to that of large-scale ones.

In recent decade, we have designed and built a lot of small ammonia plants at a capacity of 200-300 tons per day, using natural gas, refinery off gas and coke oven gas as feedstocks. As locally available gaseous feedstocks at low cost are used, the economic viability of these ammonia plants has been proved to be good.

These natural gas-based ammonia plants have the same typical process consisting of the following steps: desulfurization, primary and secondary steam reforming, high and low temperature shift conversion, carbon dioxide removal using solvent method, methanation, compression, synthesis and refrigeration. The simplified typical flow diagram is shown in Fig. 1.

An ammonia plant with a capacity less than 600 STPD employing such typical flow diagram has the following features:

1. Reciprocating compressors are used. As is well known, the efficiency of reciprocating compressor is higher than that of centrifugal compressor. This has won more and more considerations, especially in present days when the price of natural gas is soaring so high. Internationally, some corporations specify the following criteria as guideline for design: reciprocating compressor is to be used for natural gas based ammonia plant with capacity less than 600 STPD and the total elecrical energy consumption will be 735 kwh per tonne ammonia, while centrifugal compressor is to be used when the capacity of the plant is larger than 600 STPD and the corresponding energy consumption will be 755 kwh. The energy consumption of the former is 2.7% lower

than that of the latter due to its high compression efficiency. The other merit is that two pieces of reciprocating compressors are to be installed for an ammonia plant. Thus, when one compressor is being repaired, the other still can keep the plant run at half capacity. Hence, the plant is easy to maintain and the on-stream factor can be high.

2. The ammonia synthesis pressure is taken at 300 kg/cm^2. The synthesis pressure is mainly determined by the criteria at which the total power consumption and investment cost are the minimum. When the synthesis pressure is set at a higher level, the power consumption for the compression of fresh H_2-N_2 gas mixture to the synthesis pressure is high too, but the net ammonia increment of the synthesis circulating gas through the ammonia converter is also high, so the refrigeration required for ammonia condensation and the power consumption for the compression of circulating gas and the fresh gas mixture will be less. The total power requirements for the fresh H_2-N_2 mixture gas compressor, synthesis gas circulating compressor and refrigerating compressor of 220 MTPD and 500 MTPD ammonia plants in comparison with typical 1000 MTPD plant are shown in Table 1. The result indicates that the plant adopting 300 kg/cm^2 as synthesis pressure consumes less electric energy than the plant using 150 kg/cm^2 as synthesis pressure.

3. The pressure of by-product steam is chosen at 40 kg/cm^2 (absolute). In recent two decades, the scale of ammonia plant has increased ten times, but the total power required for the production of one ton ammonia remains nearly the same. The total power per ton of ammonia for a 180 MTPD plant with synthesis pressure at 300 kg/cm^2 gauge designed by us is 876 kw. However,

its total energy consumption is 21% greater than that of a 1000 MTPD plant. Thus, in the course of designing an ammonia plant, integrated heat utilization of the whole plant must be treated as a main problem which should be deliberately considered. In a 200-300 MTPD ammonia plant, for the purpose of simplicity of operation and maintainance, 40 kg/cm^2 absolute is chosen as the pressure of by-product steam, and a relatively good result of integrated heat energy utilization is obtained.

Table 1. Effects of synthesis pressure on compression power requirement

Items	Description	220 MTPD	500 MTPD	Typical 1000 MTPD
1	reforming pressure kg/cm^2 gauge	24.5	35	35
2	ammonia synthesis pressure kg/cm^2, gauge	300	300	150
3	type of compressor	reciprocating	reciprocating	centrifugal
4	total power requirements for fresh H_2-N_2 gas mixture compressor cricu-lating and refrigerating compressor kw	4943	10320	23162
5	total energy consumption for the three compressors kwh	537	496	556.8

A material flow diagram of a steam-power system for a 220 MTPD ammonia (integrated with a 350 MTPD urea plant) plant is shown in Fig. 2. The steam reforming pressure is 24.5 kg/cm^2 abs. The parameters of the 68 MTPD steam generated in the reforming system is 40

kg/cm^2 abs. pressure, superheated to $435^{0}C$. The steam first drives the back pressure steam turbine of a flue gas blower and the extraction-condensing turbine of a generator; the steam exhausted at pressures of 26 kg/cm^2, 14 kg/cm^2 and 6 kg/cm^2 abs. can be used as process steam in the reforming process and as the heating medium for the ammonia-urea plant. 6180 kw electricity, approximately one half of the requirement for the plant, can be obtained. The process heating steam of urea plant is considered as an integrated part of the heat energy utilization system, so that the total energy requirement per tonne of ammonia could be reduced considerably.

4. The feedstock supply of this type of plant is easy to ensure. As for a 220 MTPD ammonia plant, the annual consumption of natural gas is only seventy-four million cubic meters, a relatively small quantity so that local resource can be utilized directly. We have designed a 240 MTPD steam reforming plant by using refinery off gas as alternative for natural gas. The reforming pressure is 24.5 kg/cm^2 gauge. The feedstock comes from the delayed coking unit of the refinery, the composition of which is shown in Table 2.

Table 2. Composition of feedstock

composition	vol. %	composition	vol. %
H_2	8.56	C_2H_6	12.72
N_2	1.33	C_3H_6	3.61
O_2	0.35	C_3H_8	5.95
CO	1.90	iC_4H_8	1.40
CH_4	59.03	C_4H_{10}	2.11
C_2H_4	2.84	C_5H_{12}	0.2

The feedstock contains 10% olefins. The off gas of the fluidized catalytic cracking unit containing 20% olefins is used as the fuel gas of the reformer. The olefin containing reforming catalyst is manufactured in China. The plant was put into operation in 1971 and has been operated very well ever since. The feedstock consumption is 480 Nm^3 delayed coking dry gas per tonne ammonia.

The main consumption figures of a natural gas based 220 MTPD ammonia plant with the features stated above are summerized in Table 3. The total energy consumption per tonne ammonia is 9.67×10^6 Kcal (design figure), approaching that of typical large scale ammonia plant constructed in the mid seventies. The quality of the ammonia produced meets well the urea production specifications.

Table 3. Main consumption figures for a natural gas based 220 MTPD ammonia plant

Items	Description	Consumption figures per tonne ammonia	Convert to LHV
1	natural gas for process*	664.4 (Nm^3)	5.68×10^6 Kcal
2	natural gas for fuel*	339 (Nm^3)	2.90×10^6 Kcal
3	electricity**	364 (Kwh)	1.09×10^6 Kcal
Notes: * LHV of natural gas is 8550 Kcal/Nm^3			$\Sigma 9.67 \times 10^6$ Kcal
** 1 Kwh equivalent to 3000 Kcal			(design figure)

It should be pointed out that the energy conservation technologies developed recently by the existing plants such as: further recovery of waste heat contained in flue gas to preheat the combustion air, using physical absorption process to remove carbon dioxide, adoption of ammonia absorption refrigeration instead of ammonia compressing refrigeration, recovery of hydrogen in purge gas for ammonia synthesis, etc. can all be adopted in the design of this type of ammonia plants, and the total energy consumption can be further reduced.

In conclusion, the 200-300 MTPD natural gas based ammonia plant consumes less feedstock, can utilize the scattered local gas resources and requires less investment. The total energy consumption is also reasonable.

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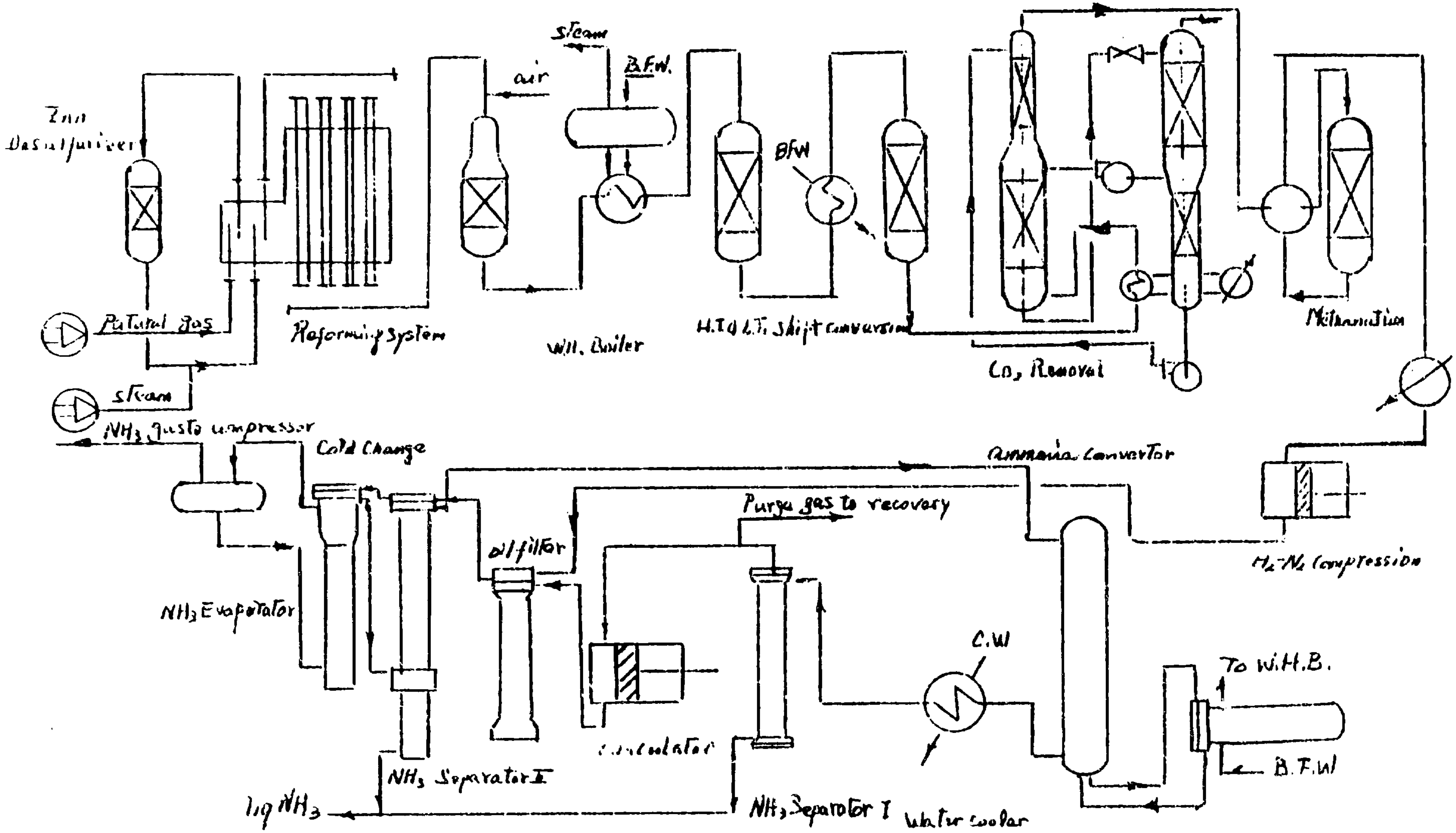


Fig. 1 Simplified Flowsheet of Typical Natural Gas Based Ammonia Plant

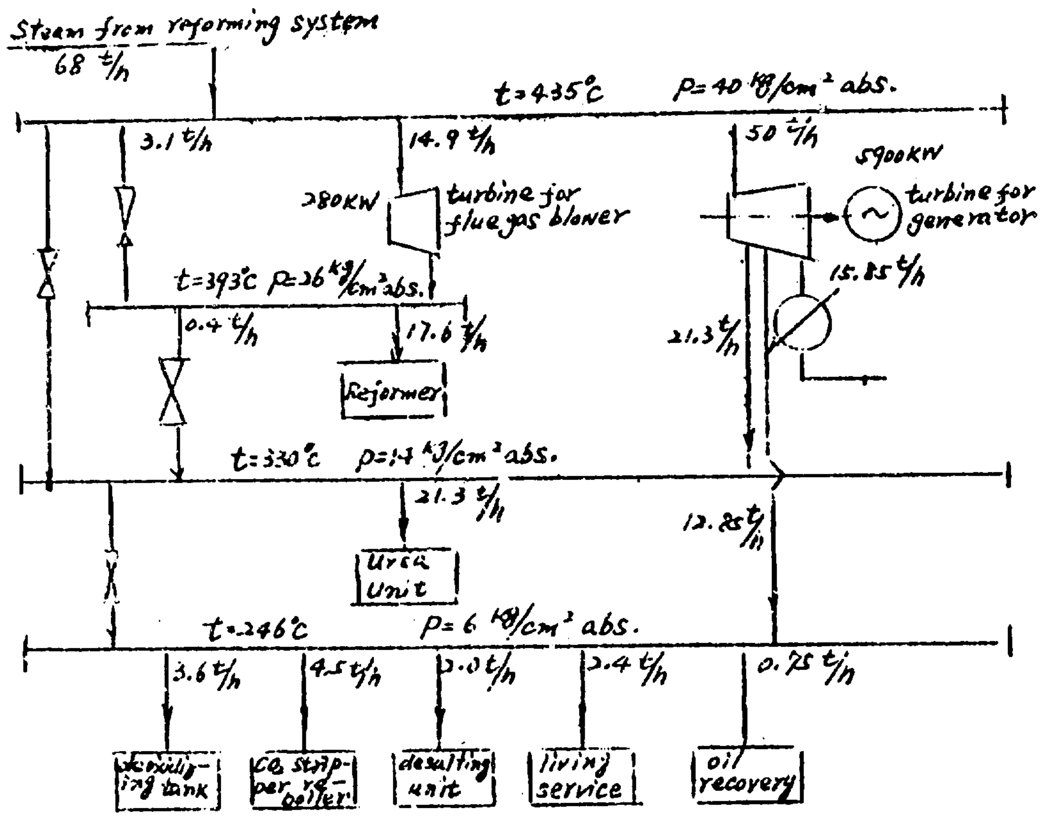
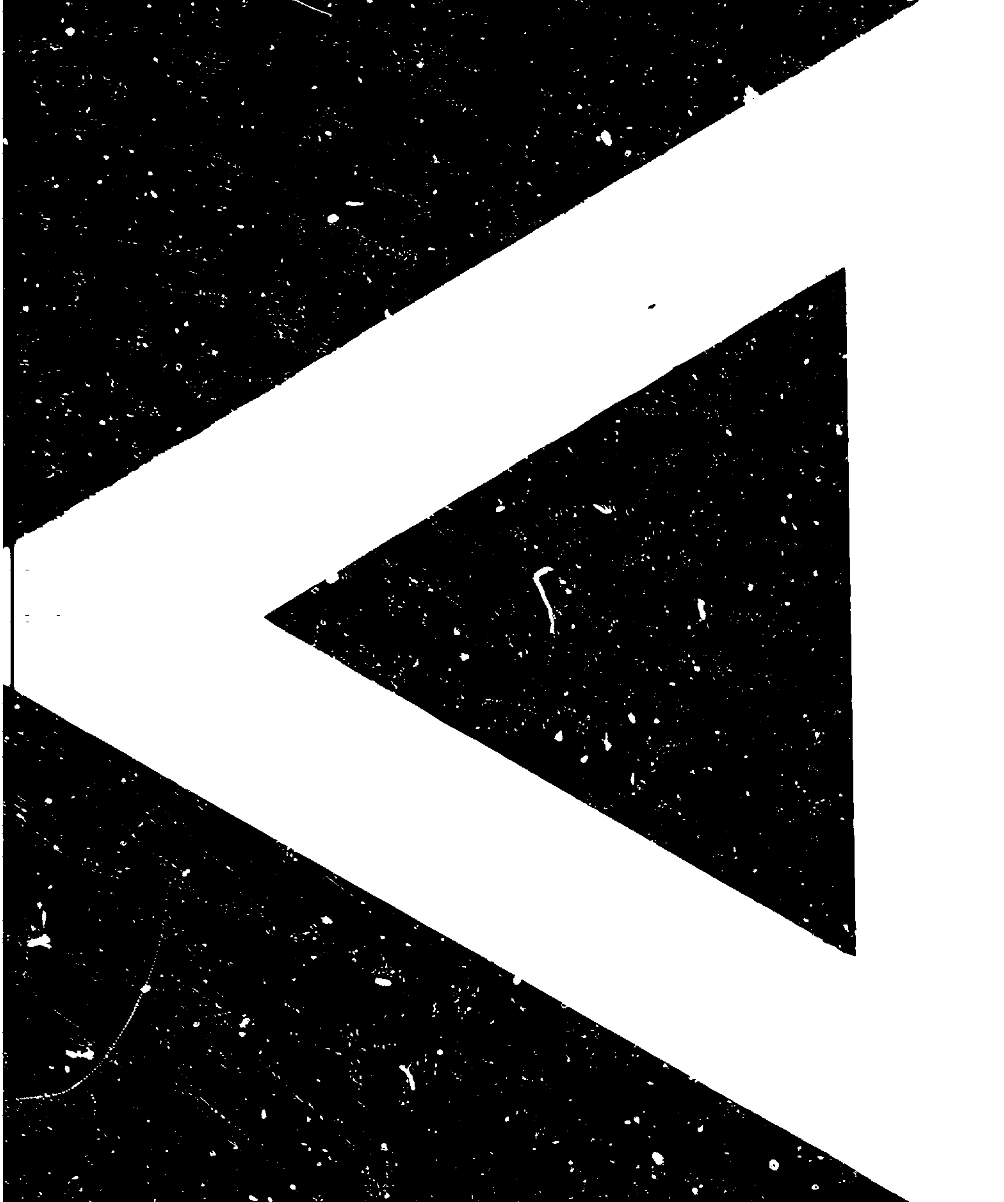
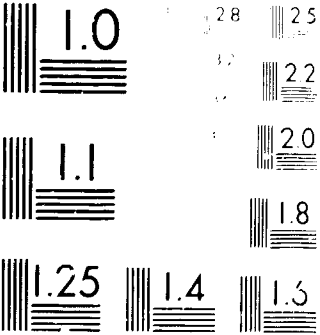


Fig 2 Material flowsheet of a steam-power system for a 220MTPD ammonia (integrated with 350MTPD urea) pant

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