Operating information of the CO_2 stripping urea plants in China

Paper 10

Author: Mrs Baoci Sun
Refining and Chemical Production Management Dept.,
SINOPEC
China

Table of contents

1. Abstract

This paper mainly introduces the reader into the current operating status of 15 CO_2 stripping urea plants built and put into operation in succession since the 1970's in China. It compares the output, the consumptions, the operating periods etc. in the early stage and in recent years. It also mentions the measures taken to optimize the process controls, slow down the equipment corrosion and eliminate the bottlenecks of the units.

2. General introduction of large-scale urea units in China

There are nearly 200 urea plants in China, divided into large-scale plants (more than 480kt/y), middle-scale plants (480 kt/y < 110kt/y) and small-scale plants (110 kt/y < 40kt/y). Both middle-scale and small-scale urea units apply Chinese domestic technology, while the most of the large-scale units operate with imported processes

A. Since 1970's, 27 large-scale urea units have been built and put into operation in China. The total production capacity has reached over 13.64 million tons per year.

These units are:

- 2 units using the Japanese Mitsui-Toatsu C-Improved Process.
- 15 units using the Dutch traditional Stamicarbon CO_2 Stripping Process.
- 9 units using the Italian Snamprogetti NH_3 Stripping Process.
- 1 unit using the Japanese TEC-ACES Process

Another two urea units using the NH_3 Stripping Process are presently under construction. The estimated total production capacity of the large-scale urea units in China will be over 15 million tons in Y2K.

B. Of the 15 CO_2 stripping urea units, 11 plants were commissioned in the1970's, 3 plants in the 1980's and the last one in 1997.Most units have therefor been operating for 15-20years. (see Table 1 for details).

Table 1: Information on 15 traditional Stamicarbon CO_2 Stripping Urea Units

NO.	Units	Design capacity		Initial start-up date	Year of meeting design value	Years on Stream
		10Kt/a	T/d			
1	Daqing	48	1620	1976.9.6	1978	23
2	Liaoning	48	1620	1976.9.29	1983	23
3	Luzhou	48	1620	1976.10.27	1979	23
4	Cangzhou	48	1620	1977.4.2	1979	22
5	Yunan	48	1620	1977.10.30	1979	22
6	Chishui	48	1620	1978.9.30	1984	21
7	Nanjing	52	1740	1978.10.9	1985	21
8	Anqing	52	1740	1978.11.30	1987	21
9	Guangzhou	52	1740	1978.12.7	1994	21
10	Hunan	48	1620	1979.6.29	1985	20
11	Hubei	48	1620	1979.8.10	1985	20
12	Zhenhai	52	1740	1983.12.26	1987	16
13	Xinjiang(1)	52	1740	1985.7.31	1991	14
14	Ningxia	52	1740	1988.7.15	1995	11
15	Xinjiang(2)	52	1740	1997.5.23		2

3. Current operating status of CO_2 stripping urea units in China

All 15 CO_2 Stripping urea units apply the traditional CO_2 Stripping process of Stamicarbon. In the early days, high NH_3 consumption, low production load, short operating periods and shut downs due to accidents were in rather common. After many years of practice all plants have improved the production capacity, consumptions and onstream timew by evaluating and optimizing their own operational procedures and incorporating both, domestic and foreign technology and experience. in the meanwhile, all plants have achieveda high level of experience in process optimizing and the execution of technical modifications.

3.1 Considerable increase in Urea output

(1) During the early period of the first to the third year of operation, most of the plants didn't reach the design capacity. The annual production output typically was just 45~80% of the design. The best unit produced about 95% of the design. The reasons for this lack of performance were:
- Low onstream time due to many shut downs resulting from equipment troubles and external reasons.
- Low daily production load because of raw material problems and lack of experience didn't bring the units capabilities into full play.

(2) After being in operation for 4 or 5 years, most plants met the targetted design production capacity through reinforcing the management and improving the operations in the plants..

(3) During the last decade, modification for improving the operating reliability of equipment as well as eliminating bottlenecks have been carried out in each plant. Except one new unit, commissioned in 1997, all other 14 units can exceed their design capacities by 2~8%, whereby the best unit reaches above 113% of its design capacity.
Summarizing:
- Six plants have an annual output above 600 kt, (Nanjing 681 kt, Zhenhai 682 kt, Ningxia 613 kt, Guangzhou 604 kt, Hunan 601 kt, Daqing 601 kt).
- Five plants have an annual output between 540 kt and 600 kt (Anqing 593 kt, Luzhou 556 kt, Yunnan 551 kt ,Xinjiang (1) 550 kt ,Hubei 540 kt)
- Nanjing's plant annual output has been over 550 kt from 1993 onwards, in 1995 the output was 590 kt and 1996 reached 681 kt, this last figure being 131% of the design capacity.
- The Zhenhai plant has produced over 590 kt/y from 1994 onwards, in 1998 the urea output was 682 kt which was a record high.

Table 2: The Annual Urea Outputs in early stage compared to recent years.

NO.	Units	Early stage	1995	1996	1997	1998
1	Daqing	356	552	577	574	601
2	Liaohe	236	484	486	480	516
3	Luzhou	362	495	483	521	556
4	Cangzhou	457	433	481	482	504
5	Yunan	381	512	516	512	551
6	Chishui	383	517	445	546	640
7	Nanjing	215	592	681	603	630
8	Anqing	261	470	551	474	593
9	Guangzhou	282	530	540	604	565
10	Hunan	351	470	512	601	589
11	Hubei	281	560	540	528	507
12	Zhenhai	246	560	635	591	682
13	Xinjiang(1)	273	582	550	540	540
14	Ningxia	251	544	535	613	611
15	Xinjiang(2)	350			149	350

Notes:

- Early stage means the next year after the initial start-up.
- Chishui's output in 1997 and 1998 include the production of an additional new small urea unit.

3.2 Significant drop in consumption figures.

(1) In the early stage, the consumption of the raw materials NH_3 and CO_2 were high in most of units. An NH_3 consumption per ton of urea of over 600 kg in average was measured, the lowest value was over 590 kg, still far from the design figure of 580 kg/ton. The same was true for the CO_2 consumption ,which was over 800kg/ton The reasons for these high consumptions were as follows:

- The original design (with single desorber) was not perfect, resulting in a large quantity of discharged effluent during the normal operation.
- Frequent start-ups and shut-downs resulted in more than normal effluent discharges.

(2) In recent years the optimalisation of operations, the enhanced integrated management and some added necessary technical modifications improved the ' operating safety of the units, made them more stable and consequently improved on the onstream times.

As a consequence the typical consumptions greatly decreased.

- Since 1990, the average NH_3 consumption decreased to 583 kg, the CO_2 consumption has dropped to 770~785 kg.
- In 1996, the average NH_3 consumption decreased below 583 kg, while the CO_2 consumption basically met the design value of 770 kg.
- By the end of 1997, 7 plants (Zhenhai, Xinjiang, Ningxia, Nanjing, Hunan, Hubei and Guangzhou) each had decreased the NH_3 consumption to less than 580 kg/ton, 2 plants (Daqing and Liaohe) each had decreased to below 582 kg/ton.
- The Zhenhai plant has been achieving the lowest NH_3 consumption among the Stamicarbon domestically built urea units since 1990. Presently its specific NH_3 consumption per ton of urea is just 573 kg. (See table 3).

Table 3: NH_3 consumption per ton of urea in early stage and in recent years
Unit: kg. NH_3/t urea

NO.	Units	Early stage	1995	1996	1997	1998
1	Daqing	628	584	582	582	582
2	Liaohe	640	588	583	582	581
3	Luzhou	597	598	604	604	588
4	Cangzhou	604	585	586	589	593
5	Yunan	600	585	585	585	586
6	Chishui	591	587	585	584	585
7	Nanjing	591	580	578	579	578
8	Anqing	597	583	582	586	580
9	Guangzhou	598	582	580	580	581
10	Hunan	590	585	582	580	579
11	Hubei	598	582	582	580	585
12	Zhenhai	589	578	576	574	573
13	Xinjiang(1)	590	579	580	577	578
14	Ningxia	640	582	579	578	575
15	Xinjiang(2)	610				611

3.3 Increasing onstream time and plant load

(1) In the early stage, mainly because of frequent emergency shutdowns the average operating days per year were less than 250 (only 65 %). The average plant load was only 74%.

(2) Since 1990, the onstream factors of all units generally have increased to over 80% with plant loads over 90%. The best unit has operated 361 days in one year. A highest average plant load of 110% has been achieved in another unit.

(3) The performance level of the units is as follows:

- The average operation days per year of ten plants exceed 330days.
- Three plants (Nanjing, Hunan, Zhenhai) each have an average daily load factor as high and above 107% achieving an average daily output up to 1920-1980 tons as highest load, while another 3 plants' (Hubei, Zhenhai and Daqing) average daily loads are over 105%. All other plant's daily loads exceed 100%. (Refer to table 4.)

Table 4: The onstream factors and load factors in the early stage and recent years

NO.	Units	Early stage	Onstream factor/ load factor			
			1995	1996	1997	1998
1	Daqing	87 / 94	95 / 98	98 / 99	92 / 106	97 / 105
2	Liaohe	71 / 89	93 / 88	97 / 85	94 / 86	98 / 89
3	Luzhou	76 / 96	88 / 95	87 / 94	91 / 96	93 / 101
4	Cangzhou	86 / 90	92 / 80	94 / 86	95 / 86	92 / 96
5	Yunan	75 / 94	88 / 98	90 / 97	89 / 98	89 / 109
6	Chishui	82 / 78	91 / 95	87 / 87	91 / 95	94 / 106
7	Nanjing	46 / 80	90 / 104	97 / 110	88 / 107	93 / 107
8	Anqing	54 / 76	77 / 96	86 / 98	78 / 96	96 / 97
9	Guangzhou	56 / 79	87 / 96	84 / 101	95 / 100	92 / 97
10	Hunan	71 / 83	84 / 95	87 / 99	94 / 108	91 / 110
11	Hubei	57 / 85	88 / 108	88 / 104	83 / 108	82 / 105
12	Zhenhai	68 / 89	87 / 102	94 / 106	87 / 107	99 / 108
13	Xinjiang(1)	51 / 85	92 / 101	86 / 98	86 / 99	83 / 102
14	Ningxia	46 / 86	88 / 97	90 / 100	95 / 101	95 / 102
15	Xinjiang(2)					71 / 78
Unit: days in operation/365 x100						

3.4 Success in managing the corrosion in urea plant equipment

Corrosion problems may occur in urea plants, especially with high pressure equipment exposed to process fluids . To keep corrosion under control we carried out a variety of investigations and inspections, and set up strict management regulations based on the findings of such investigations and inspections.

(1) Operation:

- Strictly control the temperature rise while heating up and passivating. (heating-up rate per hour).
- In normal operation rigorously control O_2 addition, NH_3/CO_2 ratio, H_2O/CO_2 ratio and the steam pressure in shell sides of both the HP condenser and stripper.
- Control the depressurisation and cooling down rate of the equipment during shut down.
- Control the Cl^- content to maximum 0.5 ppm in high and low pressure boiler feed water, steam condensate and condensate in the shell side of the high pressure carbamate condenser.

- Perform according a fixed schedule the necessary analyses of contaminants such as Ni content in the whole process system, Cl^- in recycle water, Cl^- and NH_3 in boiler feed water and steam condensate..
- During overhauls maintenance procedures should be strictly followed and the materials and the welding rods used must be according to the pertaining specifications.

（2）Managerial

Regular management attention plays an important role in slowing down equipment corrosion and consequently expanding the equipment' life time and thus ensuring stable operation. As a result equipment running for nearly 20 years can still be in good condition and the originally with the expected life time can be achieved. Some equipment of the units whose initial start ups were in the1970's needed renewal in after 1993. Refer to Table 5.

Table 5: The replacement and repair situation of the 4 High Pressure Equipment in 15 Plants

Item	Replacement and repair situation	Number of plants
Stripper	Replacing the whole stripper	9
	Plugging some tubes	3
	Replacing both upper and bottom channels	3
High pressure condenser	Replacing the whole HP condenser	9
	Replacing the tubes	9
High pressure scrubber	Replacing the whole HP scrubber	5
	Replacing the tubes	4
	Repairing or relining the top head.	9
Reactor	Replacing the whole reactor	0
	Repairing the lining of the cylinder	5
	Repairing the lining of the head	4
	Replacing the trays	8
	Replacing the downcomer tube	6

4. Technical Modifications and Measures performed to improve plant performance.

4.1 Measures and modifications to optimize the process control

(1) Install orifices at the top ends of the gas risers of the stripper to improve gas distribution and increase stripping efficiency.
(2) Install flow restriction plugs (with holes) at the bottom ends of the tubes in the recirculation heater to achieve proper liquid distribution and to eliminate internal recycle with as consequence the increase of the temperature at the liquid outlet of the heater.
(3) Apply chemical cleaning or high pressure hydroblasting to clean fouled tubes in recirculation heater and stripper to improve heat transfer and stripping efficiency.
(4) DCS control systems have replaced the conventional instruments. These computerized control systems enhance the adjustability and stability of the operation, providing better unit operation and fewer emergency shutdowns.
(5) Apply modern compressor control systems and pump monitoring technology. Five plants have used CCC control systems from the USA for the whole CO_2 compressor train, improving the performance of the speed controls and consequently a more stable and more energy efficient capacity control.
Some other plants have modified the CO_2 compressor's control systems with domestic technology, improving the performance and ensuring stable operation of the CO_2 compressors.

4.2 Measures to slow down equipment corrosion

(1) Applying H_2O_2 passivation technology is very useful to alleviate equipment corrosion in the high-pressure system and also reduces the amount of anti-corrosion air by 400~500 Nm^3/h, thus increasing the CO_2 capacity of the compressor correspondingly.
(2) Applying domestic corrosion monitoring equipment, based on Stamicarbon's inspection technology (for the high-pressure loop of the urea plant) provides a convenient and continuous monitoring of the corrosion status of high pressure equipment and provides fast information about the relative extent of corrosion eventually occurring in the plant.

4.3 Elimination of bottlenecks to increase the production capacity

Depending on the different bottlenecks in various units, different measures are taken to achieve the goal to increase.the output.

The main modifications are:

(1) Change existing reactor trays which are in need of replacement with high efficiency reactor trays using domestic or foreign technology. These high efficiency trays are very useful to reduce liquid back-mixing in the lower part of the reactor, increasing CO_2 conversion rate by 2%, the stripping efficiency by 2~3%. The steam consumption in stripper decreases correspondingly and the operation of both 7 kg and 3 kg steam systems improves distinctively.
(2) Lengthen the tubes of the recirculation heater, so achieving a temperature at the outlet of the rectifier up to 135 ^{o} C in combination with a plantload of about 110%.
(3) Add another recirculation heater, a low pressure carbamate condenser and a pre-evaporator to unload the existing recirculation system and increase the production capacity.
(4) Renew or upgrade the urea solution pump, increasing the pumpcapacity to 140 m^3/h. Also add a new small ammonia pump and a carbamate pump with capacities of 13.6 m^3/h and 11.6 m^3/h respectively. With the small NH_3 pump operating, the load flexibility of the original ammonia pump is increased and the rotating speed of the turbine can be reduced by about 600 rpm still meeting the requirements of the unit's load at 110~115%. Up to 110 % load the additional small carbamate pump is not yet required.
(5) Revamp the four ejectors in the evaporation vacuum system using domestic technology with the objective to achieve the proper vacuum also at loads upto 110%. A proper vacuum is defined as 0.0034 Mpa, achieved in combination with a steam pressure of 0.3 Mpa.
(6) Improve CO_2 inlet cooling to lower the inlet temperature of CO_2 compressor with the purpose to increase the delivery volume of the compressor.

4.4 Measures to improve the quality of urea prills

The limitations of the original design affect the particle size, the strength of the urea prills and the temperature at the exit of the tower. To tackle the key technical problems, being, small prillsize, weak strength and a large amount of dust, the plants placed emphasis on the management and optimization of the prilling process. A series of necessary measures were taken:

(1) To raise the strength of urea prills, formaldehyde was added into the urea melt, increasing the crushing strenght of the prills by about 10%~30%, reducing the ammonia smell and reducing the dust formation in the bulk storage, with as a consequence less lumps in the bulk storage. .
(2) Modifications of the four ejectors in the vacuum system of the evaporation section basically resolved the vacuum problems at higher.load. Insufficient vacuum results in high water content in the urea melt fed to the prilling tower.

(3) The prilling bucket was modified because with the original bucket, the urea particles prilled within a spraying radius of 2 meters were too small (the size of about 22% of prills was less than 1.0%).

- Properly enlarge the hole diameter and adjust the hole distribution. Use the modified prilling bucket with the proper hole diameter according to the requirements related to different air temperature and production load to improve the particle size of the prills.
- Develop a new prilling bucket, improving on the hole number, the hole opening direction and hole diameter to get larger, stronger urea prills and less dust.

(4) Improve the ventilation of prilling tower.

(5) Add vibrating screen to sieve the urea before bagging to ensure a final product with a high quality appearance.
Urea dust can be used as feed stock for NPK fertilizer.

<u>4.5 Measures to reduce consumptions</u>

(1) Fourteen plants have installed deep hydrolysis units to treat the process condensate.produced in the urea plant.

- Nine plants use foreign technology. Both the urea and ammonia content in the treated process water fall below 5 ppm in these plants. Five of these plants use the treated process water as boiler feed water for the medium pressure boiler.
- The remaining five plants apply domestic technology. Their urea and ammonia contents are below 50 ppm. The waste water containing this ammonia is used as washing water for other equipment.

(2) While installing the hydrolysis, each plant has added a low pressure or atmospheric tail gas absorption system in which ammonia recovery from tailgasses takes place through condensation and scrubbing in a packed column, thus reducing ammonia losses.

5. Conclusion

With a new century beginning, we still have to put more efficient efforts in operating our plants, moreover we should adopt continuously advanced experience and technology to improve the existing processes and facilities.
Only by improving the operating performance and thus reducing the production cost can we gain more competitive power to face the challenges from the international market.