

IFA Technical Conference

**Beijing, China
20-23 April 2004**

OPERATING EXPERIENCE OF THE BENFIELD CARBON DIOXIDE REMOVAL SYSTEM AT RUWAIS FERTILIZER INDUSTRIES (FERTIL)

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ABSTRACT

FERTIL has been operating an Ammonia/Urea Complex since the end of 1983. The Ammonia Plant is based on Haldor Topsoe Technology license and incorporates a Benfield carbon dioxide removal section, employing hot potassium carbonate solution, licensed by UOP of USA.

The name plate capacity of the Ammonia Plant was 1,000 MTPD, which was enhanced to 1,050 MTPD by incorporating a cryogenic purge gas recovery unit in 1988.

The plant capacity has been progressively increased over the years and the plant currently operates at 130% of the name plate capacity consistently. This has been achieved without undertaking any formal debottlenecking. However, various in-house studies were carried out and minor modifications implemented to achieve the present rate of production.

This paper describes the operating experience of the Benfield CO₂ removal section, detailing the problems faced in it and subsequent corrective actions taken to:

Alleviate the problem of Regenerator Tower carryover.

Solve the problems of foaming and high level of hydrogen content in the acid gas.

Replace the conventional DEA activator with ACT-1, which has resulted in increased throughput, reduced CO₂ slip and reduced heat consumption.

The elimination of DEA from solution resulted in solving the problem of amine degradation, dark colour, foaming, vanadium reduction and high consumption of potassium nitrite, etc.

Received 15 January 2004 for presentation at the 2004 IFA Technical Conference, 20-23 April, Beijing, China

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1. INTRODUCTION

Based in the Ruwais Industrial Zone, on the Gulf coast of Abu Dhabi in the United Arab Emirates, the Ruwais Fertilizer Industries (FERTIL) complex has one ammonia plant and one urea plant with design capacity of 1,050 MTPD and 1,500 MTPD respectively. The complex also includes fully integrated utilities plant, storages, loading and shipping facilities.

The complex was designed and constructed by the Chiyoda Corporation of Japan, based on the technology licence and know-how of:

- Haldor Topsoe A/S, Denmark : ammonia
- Benfield Corporation, USA : CO₂ removal
- Costain Engineering, UK : hydrogen recovery
- Stamicarbon b.v., Netherlands : urea

Ammonia Plant was commissioned at the end of 1983. the plant initially had a rated capacity of 1,000 MTPD which was later increased to 1,050 MTPD by incorporating a Hydrogen Recovery Unit.

The Plant achieved a capacity of more than 100% consistently every year from 1985 till date. From 1986 to 1994, the ammonia plant on-stream factor averaged around 88%. Sustained efforts were started in 1995 to increase the plant load and improve the reliability.

In 1999 the on-stream factor achieved was 100% with a capacity utilization of 126.9%. Though the average load was above 30% consistently during 5 months in 1999, the limitation to run continuously the plant at this load or more was the CO₂ Removal Unit.

Brief Description of the CO₂ Removal Unit and summary of the Operation Problems Experienced:

The Benfield HPC Unit in FERTIL Ammonia Plant is designed to remove the CO₂ content of the gases exit L.T. Shift Converter Units and consists of all usual equipments using single stage flash with single ejector.

Carbon dioxide is removed by absorption in hot aqueous HPC solution containing 30 ~ 31 wt% potash (K₂CO₃) partly converted into bicarbonate (KHCO₃). The solution further contains an activator, originally DEA (replaced by ACT1 in 1999). Also vanadium is added to the solution as a corrosion inhibitor and when necessary potassium nitrite KNO₂ is used for maintaining V5 content.

The gas is passed to the CO₂ absorber (C1301), which is a column containing Hy-Pack arranged in four beds (Figure 1). The two upper beds are 7,315 mm high each and have a diameter of 2,134 mm and contain totally about 52.3 M3 of 1.½" carbon steel Hy-Pack. The two lower are 8,534 mm high and 7,034 mm high respectively and have a diameter of 3,353 mm. They are identical and contain a total of 176.4 M3 c.s. 2" Hy-Pack.

On top of each bed is a 610 mm layer of 2" stainless steel Hy-Pack, and a 1,500 mm layer of 2" stainless steel Hy-Pack is packed at in the bottom of the lowest bed. In the absorber the gas flows upwards against a descending stream of potash solution.

The CO₂ is removed from the gas according to the following chemical reaction:



The reaction rate is kept high by the combined effect of the high temperature and the activator.

The gas which contains about 18 mole% of CO₂ on a dry basis before the absorber will contain about 0.1% of CO₂ after passing the absorber.

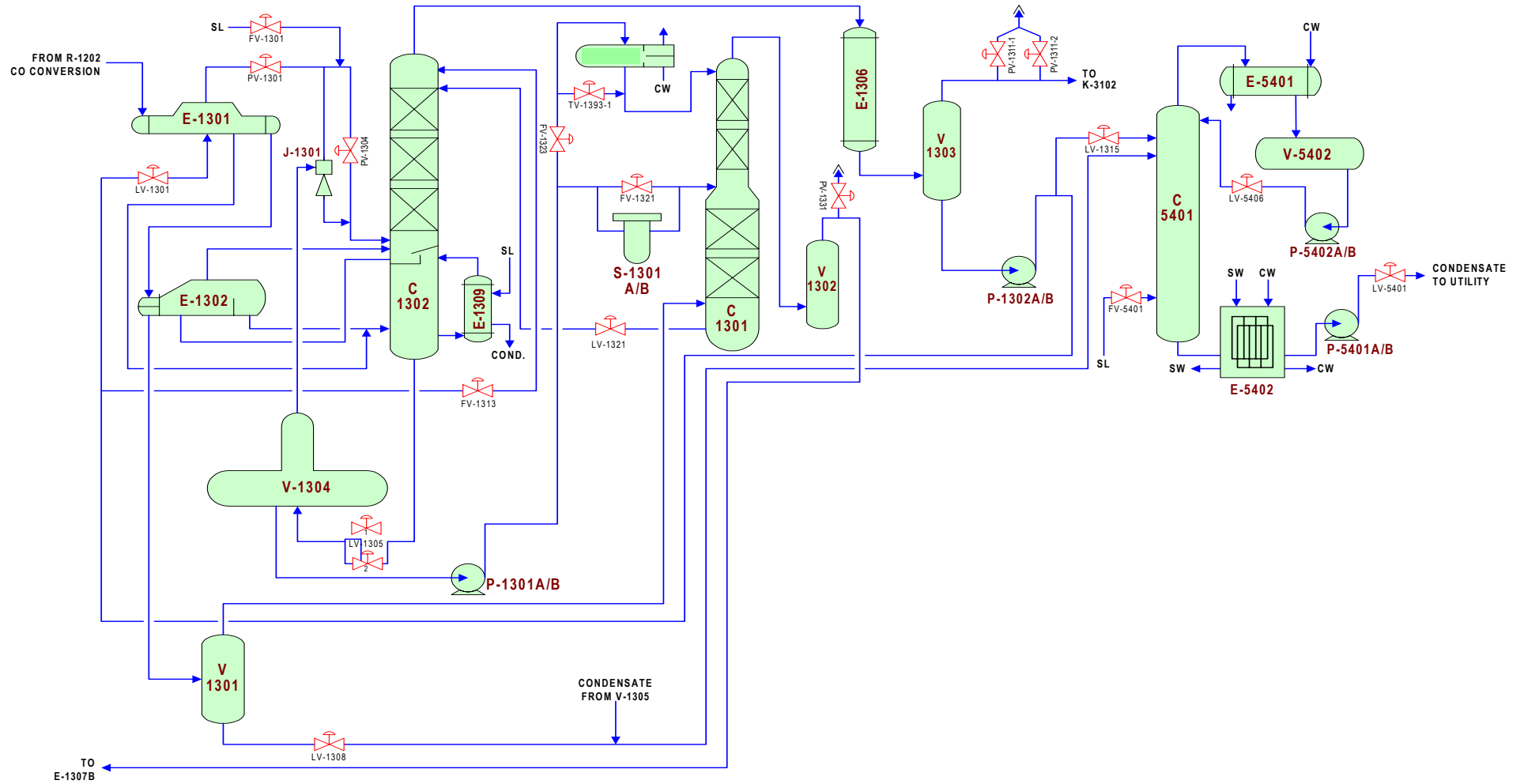
The potash solution loaded with CO₂ from the absorber is regenerated according to the above equation reading from the right to the left, in the HPC Regenerator (C1302) for continued re-use. The tower contains three beds of Hy-Pack. The beds are 8,534 mm high each and have a diameter of 4,267 mm, and contain a total of 365.9 M3 of 2" carbon steel Hy-Pack. On top of each of the three beds is placed 610 mm 2" stainless steel Hy-Pack.

The spent potash solution is discharged into the top of the tower, where the pressure is reduced to 0.8 kg/cm²g and part of the CO₂ is flashed off. The remaining CO₂ is removed from the solution by flowing downwards through the tower in counter-current with the steam. In the top of the regenerator above the rich solution distributor, water washing section consists of two valve trays and demisters. Overhead vapours are washed with reflux condensate which is piped down to the re-boiler shell side, near its tube sheet. After having passed the regenerator, the HPC solution flows to the flash tank (V1304) where additional steam for the regeneration is raised by flashing the solution. V1304 is evacuated by means of the steam ejector (J1301), using the direct regeneration steam as motive force. The regenerated and flashed solution is pumped by the HPC circulation pump (P1301AB) to the Absorber (C1301). Approximately 20% of the solution is cooled to 62°C and introduced into the top of the Absorber, whereas the main part is going to the upper one of the lower beds.

The problems experienced in the CO₂ Removal Unit since 1985 are related below. The steps taken to solve them and the resolution approach are discussed.

Figure 1

CO₂ REMOVAL & PROCESS CONDENSATE RECOVERY UNITS



2. OPERATIONAL PROBLEMS EXPERIENCED IN THE CO₂ REMOVAL UNIT

* Carry over of carbonate solution:

There has been a continuous carry-over of carbonate solution from the regenerator overhead into the acid gas. This has caused the loss of considerable chemicals and also water when the excess condensate water cannot be recovered and must be dumped.

- H₂ Slippage: There has been a problem of excess H₂ slippage with CO₂. Problem increased in intensity from 1997 to 2000, affecting the plant load of ammonia and urea plant.
- Foaming/DEA degradation and particulates in the system.
- Corrosion

3.1 Regenerator carry-over and rich solution distributor mechanical damage (Figure 2)

- Since commissioning carry-over of potassium to HPC overhead condensate has been experienced for short duration when there is foaming upset in the regenerator tower. However persistent carry-over has been experienced from November 1986 to April 1987 (Table 1), then from November 1987 till turnaround 1988 in January and then finally from July 1989 till turnaround in June 1990.
- During unplanned shut downs or turnarounds in April and October 1985, April 1986, April 1987, January 1988, April 1989 and June 1990, the top of the regeneration tower was inspected and the following damages were found:
 - In April 1985 and October 1985: The rich solution piping (Ring Type) found damaged. A central pipe was added. To solve the problem of damage of rich solution internal nozzle Chiyoda proposed to install a Flashing Diverter Distributor which material was procured by end 1986. As in April 1986 turnaround the ring type distributor was found in good condition, it was decided to defer the change of the original distributor.
 - On 18.10.1986, persistent carry-over appeared for the first time. The carry-over was continuously increasing and part of the overhead condensate surplus started to be dumped.
 - In April 1987, when plant was shut down due to leak at absorber exit sample, opportunity was taken to check C1302 internals. Distributor flange on central pipe was found separated. Trays and demisters found scaled.
 - After few months of operation, in November 1987 carry-over started again and reached an average of 1000 ppm before the turnaround shutdown in January 1988, and forced the dumping of all surplus condensate. The ring type distributor found to have minor damages. Trays and demisters found scaled. The ring distributor was changed to flashing diverter type proposed and supplied by Chiyoda in 1996.
 - In February 1989, the carry-over appeared again and reached 70 ppm of K+.

- In April 1989, the plant was shutdown due to waste heat boiler tubes leak. C1302 regenerator was inspected during the shutdown. The flashing type distributor (installed in January 1988) was found to have extensive damages. Various welds, plates as well as ribs have wide cracks. Trays/demisters found scaled.

Corrective actions taken were (Figure 3 and 4):

- Trays fully cleaned and demisters replaced.
- 5 Nos vent holes provided on Top Slopped Raffle of the shroud to minimise gas turbulence. Vent holes consisted of 6" nipples with caps on top.

In July 1989 the carryover started again, reaching 3500 ppm of K+ before 1990 turnaround in June.

- During turnaround 1990 the regenerator top was inspected. Trays and demisters found fouled with hard materials. Most of valves found in stuck position.

Corrective actions taken were:

- Trays and demisters cleaned.
- Vent holes on diverter nozzle provided with Chinese-hats for vapour disengagement.
- Rich solution distributor provided with 10 down comers of 4 inch dia on the three troughs.

The purpose of the modification was to reduce the liquid overflow from the troughs in the passage of the rising gases as this passage was found to be inadequate.

3.2 Approach adopted to contain the carry-over

During each inspection, the trays/demisters found scaled and were cleaned.

From the observations and experiments made in laboratory the carry-over problem can be explained as follows:

- The lower washing tray receives few tons/hr of solution carry-over with CO₂ + steam.
- Few months after a plant shut down/turnaround and trays cleaning, carry-over re-appears due to the flooding of the washing trays.
- Choking of the down comers, seal pans, vortex breaker as observed during various inspections, causes the flooding.
- The build-up of deposits comes from low pH of the mixture condensate + solution and precipitation of oxides and salts; probably local evaporation and concentration favours this precipitation.

- A sample of solids taken from the regenerator overhead wash trays indicates: 46% iron oxide and 51% vanadium oxide with only small amount of potassium.
- The above explanation indicated that there was a possibility to contain the carry-over by stopping the condensate to the wash trays.
- The reduction of condensate started from November 1992 and reflux condensate to the top was cut off completely by September 1993
- Another step taken was that, in addition to the 10 down comers provided in 1990 turnaround on June, 6 additional down comers were added in 1992 T/A and 10 other down comers provided in the circumference gallery of the inlet liquid distributor in 1994 turnaround.
- Also the height of the gas risers situated on the distributor was only 150 mm. This was not considered enough to avoid liquid overflow through these risers, especially when the solution is foamy. This liquid overflow in the gas risers will result in the entrainment of liquid, thus resulting in carry-over. The height of the risers was increased to about 250 mm.

These actions resulted in containing the potassium carry-over in the overhead condensate.

No mechanical damage was experienced from 1991 and the carry-over during the period of 1991 – 1998 was less than 10 ppm.

Figure 2

ORIGINAL INTERNAL RICH SOLUTION NOZZLE (RING TYPE)

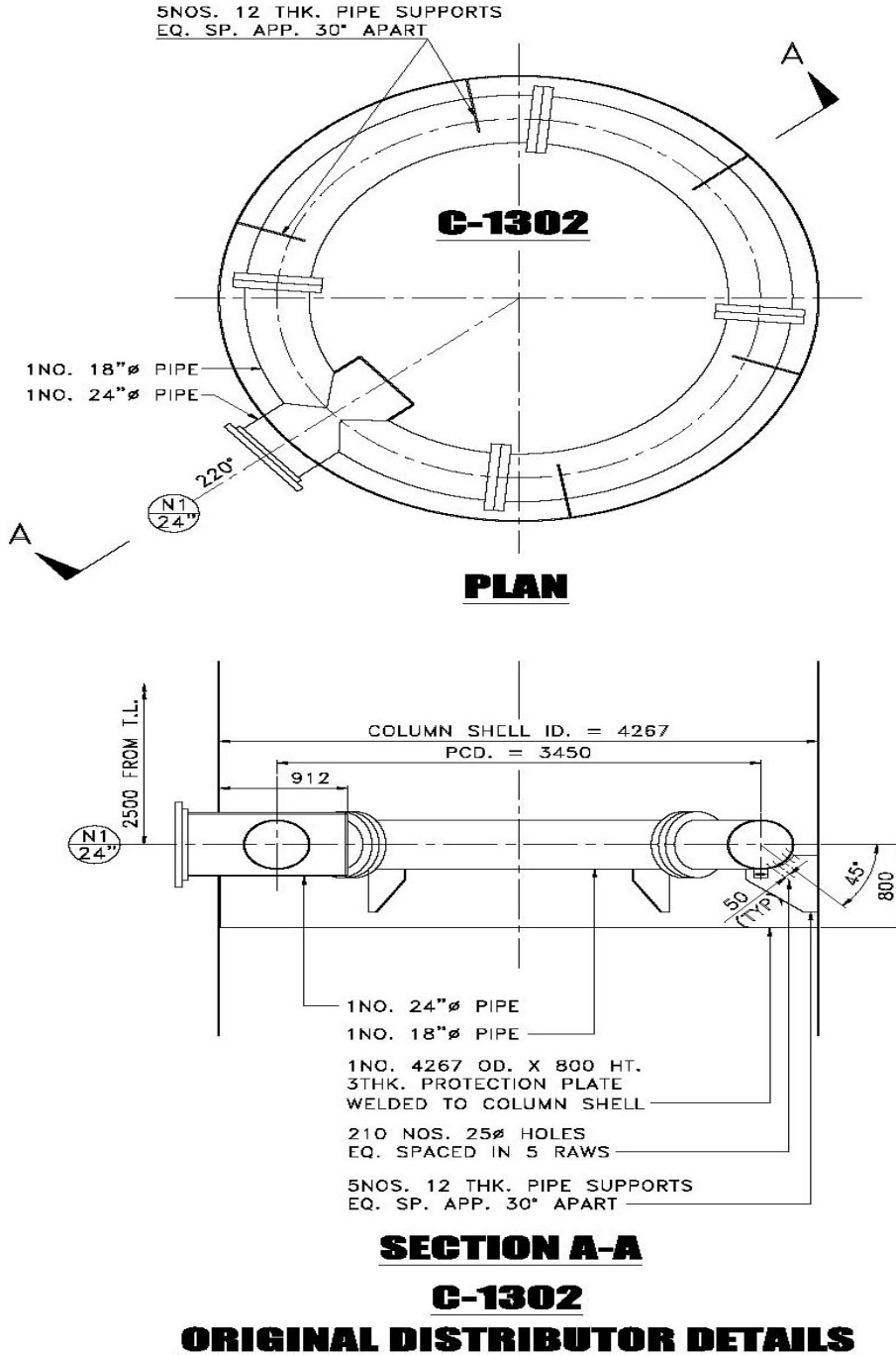


Figure 3

MODIFIED RICH SOLUTION DISTRIBUTOR INSTALLED IN JANUARY 1988
(MODIFIED IN 1989 & 1990)

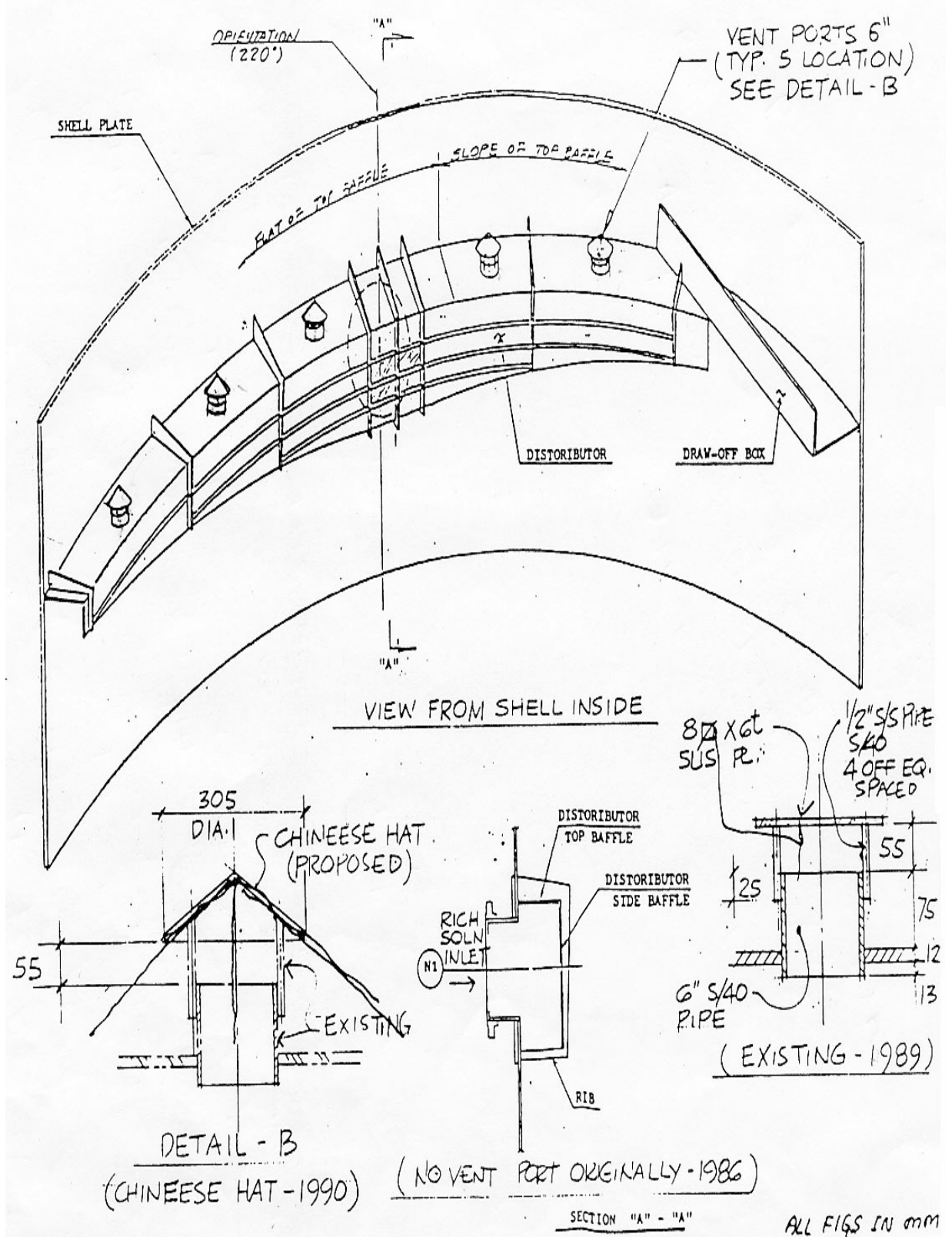


Figure 4

ADDITIONAL DRAINS BELOW THE TROUGH AND ON THE CIRCUMFERENTIAL GALLERY

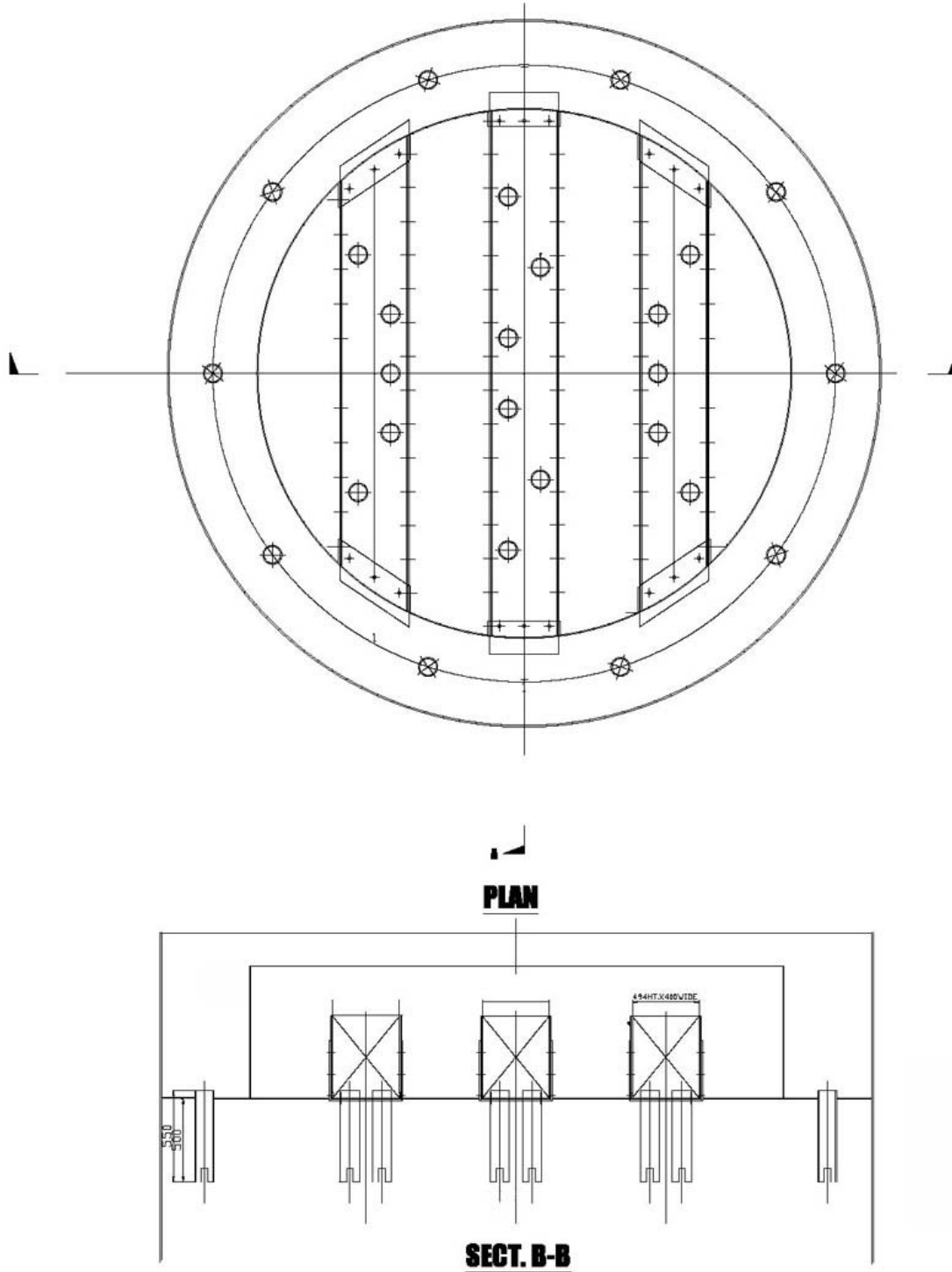


Table 1: HISTORY OF THE CARRY-OVER FEW MONTHS OF CONTINUOUS RUN AFTER TRAYS/DEMISTERS CLEANING

1986 ~ 1990

MONTH	K+ CARRY-OVER (ppm)	REMARKS
OCTOBER 1986	5	
NOVEMBER 1986	60	
DECEMBER 1986	40	
JANUARY 1987	25-	
MARCH 1987	450	
APRIL 1987	320	
APRIL 1987	420	HPC UNIT - S/D TRAYS/DEMISTERS CLEANED
JULY 1987	5	
AUGUST 1987	90	
SEPTEMBER 1987	15	
OCTOBER 1987	51	
NOVEMBER 1987	450	
DECEMBER 1987	300	
JANUARY 1988	330	T/A AND TRAYS/DEMISTERS CLEANED
JANUARY 1989	5	
FEBRUARY 1989	20	
MARCH 1989	45	
APRIL 1989	70	HPC UNIT - S/D TRAYS/DEMISTERS CLEANED
JUNE 1989	5	
JULY 1989	100	
AUGUST 1989	300	
SEPTEMBER 1989	330	
OCTOBER 1989	300	
JANUARY 1990	1200	
MAY 1990	3500	HPC UNIT S/D (T/A) TRAYS/DEMISTERS CLEANED
DECEMBER 1990	3	
JANUARY 1991	3	

**Table 1: HISTORY OF THE CARRY OVER (continued)
1991 ~ 1998**

YEAR	K+ CARRY-OVER (PPM)	REMARKS
1991	1.2 PPM	TRAYS/DEMISTERS CLEANED IN FEBRUARY
1992	1.0 PPM	EXCEPT DURING FOAMING FOR A SHORT DURATION WHEN CARRY-OVER INCREASED TO 3500 PPM. TRAYS CLEANED DURING T/A 1992 IN APRIL
1993	1.5 PPM	TRAYS/DEMISTERS CLEANED IN NOVEMBER 1993. REFLUX WATER TO TOP CUT OFF.
1994	1.5 PPM	TRAYS/DEMISTERS DURING T/A IN FEBRUARY
1995	1.5 PPM	
1996	32 PPM	NEW HIGH DENSITY DEMISTERS INSTALLED IN T/A 1996 APRIL, TRAYS CLEANED. NEW DEMISTERS REMOVED IN SEPT. AND REPLACED BY OLD
1997	1.5 PPM	
1998	14 PPM	TRAYS AND DEMISTERS FOUND LESS FOULED

Other Problems Experienced And Resolution Approach Adopted

The sustained efforts started in 1995 to increase the plant load steadily as reflected on the capacity utilization and the on-stream factor in the subsequent years.

The yearly average loads reached from 1995 to 1999 were:

1995	1996	1997	1998	1999
122.8%	124.43%	124.95%	121.35%	127%

Though the average load was above 130% consistently during 5 months in 1999, the limitation to run continuously the plant at this load or more was the Benfield HPC Unit. The following problems, added to the carry-over problem, faced in this unit and the corrective measures taken are described below:

3.3 High H₂ slippage in the CO₂ product, foaming and DEA degradation

There has been a continuing problem of excess H₂ slippage in the CO₂ product. The problem started in 1995 increased in intensity and frequency in 1997 and 1998. This problem has caused limitation on plants loads and caused trips of urea plant on two occasions. Following behaviour observed:

- DEA consumption started increasing from 1995 (Table 2).
- Although the system is designed to give up to 1% H₂ in CO₂ product, it ranged between 0.4 ~ 0.5%. After the increase of plant load, the H₂ content gradually came up to 0.7% – 0.8% in 1996 at 124.4% plant load.
- Foaming tendency increased in the system.
- When there was raw N.G. composition change, the foaming tendency increases and fluctuation severe pressure drop was experienced in the absorber.
- DEA concentration dropping indicating a degradation occurring.
- Formate content in the solution found to be high : 3.48%
- Vanadium V+5 content declining and KNO₂ consumption increasing.
- High level of suspended solids in the solution.
- HPC solution developed a dark colour.
- The variation of pressure drop in the absorber are followed by also CO₂ slip increase.
- The fluctuations of H₂ concentration in the acid gas are cyclic and appears and disappears without apparent reason.
- Cyclic variations of the H₂ slippage upto 1.8% with heavy foaming was experienced from 1995 to 1998.

From all the above observations it was clear that the root cause of high hydrogen in the CO₂ is the accumulation of DEA degradation products and increase of particulates in the system. The accumulation of DEA degradation products resulted also in increased foaming tendency, V+5 reduction, and high consumption of potassium nitrite.

Following corrective measures were taken:

Improving the filtration:

Originally there was a mechanical filter having 304 SS elements (39 Nos.) with filtering size of 100 microns or 40 microns provided for continuous filtration of slipstream (50 M³/hr) taken and returned back to the HPC stream going to CO₂ absorber.

Another side stream filter was provided in 1998 with also a capacity of 50 M³/hr. The filtering elements size from 10 microns, 5 microns, then finally to 1 micron were installed to reduce the suspended solid in the solution.

A batch filtration was added in the HPC preparation and storage section. The circuit allows batch filtration of HPC through an activated carbon filter and a mechanical filter.

The batch filtration circuit through activated carbon filter and mechanical filter was improved by integrating a temporary cloth filter (vertical round leaf type made of stainless steel wire) transferred from the pre-desulphurisation unit. The 50 microns filter elements of the mechanical filter in the circuit were replaced by 10 microns size elements.

Replacing the DEA by the Benfield Activator ACT-1

As the root cause of the foaming, discolouration of the solution, high H₂ slippage in the CO₂ product, is the accumulation of the degradation products, it was decided to replace the DEA activator by ACT-1. This new activator was recommended and supplied by UOP and claimed to provide lower CO₂ slip, and having superior stability compared to DEA. Prior to the replacement a test trial was done from July to November 1994. The test was satisfactory in term of CO₂ slip drop which reduced from 950 ppm to 610 ppm. But without water wash to the top of the regenerator the loss of ACT-1 remained very high.

From the experience of carry over of potassium in the overhead regenerator, it was expected that if we resume the wash water to the top the carry-over may reappear again.

Before starting the replacement of DEA by ACT-1, a pipe with necessary valves, flow-meter and pH-meter was provided to mix the wash water with lean solution and to maintain the pH of the mixture above 8.

The replacement of DEA by ACT-1 started in May 1999.

During the transition period of replacement of DEA by ACT-1, and by August 1999 H₂ slippage in CO₂ fluctuations experienced. This repeated again in July 2000. H₂ slippage in the CO₂ was fluctuating from 0.8% to 1.8%

Carry-over of potassium as expected started also increasing few months after resuming the wash water to the top (Table 3).

Probably due to the interaction between leftover DEA and ACT-1 in the HPC and the subsequent degradation products, foaming in the system increased. High CO₂ slip from the absorber, along with occasional increase of H₂ content in the CO₂ product, forced us to reduce the plant load.

Emphasis was laid on further improved solution filtration.

After the heavy carry-over of potassium by end of 1999 and beginning of 2000, the trays/demisters were inspected during the shut down caused by sea water failure. Both trays and demisters found scaled and were cleaned.

Again in 2000 the potassium carry-over was very heavy reaching 2000 ppm of K+ by year end. New trays were procured and plant was shut down in December 2000 to replace the existing ballast trays by Norton Provalve™ trays with high provalve lift and fixed valve arrangement having extra capacity.

The existing York-431 Demisters replaced also by York Style-194 (High density and having a removal efficiency down to below 3 microns size droplets).

The ACT-1 concentration initially <0.2 was gradually increased to 0.4% by May 2000 when DEA was only 0.1%.

By January 2001 the plant load could be increased to 131%.

Finally in view of the bottleneck of the HPC section for further increase of the plant load, the Hy-pack packing of both towers were replaced by Norton High Performance Intalox Metal Tower (IMTP) during turnaround in November 2001, to increase the hydraulic capacity.

The performance of the CO₂ Removal Unit is satisfactory as:

- Carry-over during 2003 has not exceed an average of 60 ppm after one year of continuous run.
- The CO₂ slip is at 600 ~ 700 ppm.
- The plant load reached in January 2002 & 2003 is 133%.
- The consumption of KNO₂ has reduced.
- The dissolved iron content which was at level of 120 ~ 140 ppm has reduced to 75 ~ 80 ppm.
- The consumption of ACT-1 was high from May 1999 to Decembr 1999: 5943 Kgs. During 2000 the consumption of ACT-1 was also high (10471 Kgs,), but it dropped to 6650 kg in 2001, and further dropped to 4670 Kgs. in 2002. In 2003 the consumption was about 5950 Kgs. approximately 0.0126 Kgs. per ton of ammonia.

YEAR	K2CO3 (KGS.)	DEA (L)	V205 (Kg)	ACT-1 (Kg)	POT. NITRITE (Kg)	LOAD
1989	81,000	12975	2120		3000	115.13%
1990	158,500	14580	3800		2500	112.74%
1991	3,000	8078	200		550	111.55%
1992	6,250	9452	280		650	110.24%
1993	12,750	13576	280		1500	117.90%
1994	5,250	14000	200		798	121.55%
1995	3,750	19011	NIL		2000	122.08%
1996	8,200	21069	1080		2050	124.43%
1997	18,000	28046	160		650	124.95%
1998	8,000	72202	480		650	121.35%
1999	11,000	6260	240	5943	250	126.87%
2000	91,475	NIL	3380	10471	NIL	124.54%
2001	4,400	NIL	535	6650	350	128.20%
2002	8,825	NIL	590	4811	340	126.31%
2003	15,325	Nil	525	5660	485	130 %

Table 3: POTASSIUM CARRY OVER FROM 1999 TO 2003 (AFTER RESUMING WASH WATER TO THE TOP TRAYS)

Year	1999		2000		2001		2002		2003	
	K+ Carry-over	Plant load	K+ Carry-over	Plant load	K+ Carry-over	Plant load	K+ Carry-over	Plant load	K+ Carry-over	Plant load
JAN	3.4	126.6	507.0	126.0	0.8	130.9	1.9	133.0	5.0	132.5
FEB	3.5	130.6	2.4	131.5	2.3	131.2	3.0	131.7	10.0	131.8
MAR	4.7	130.8	6.0	130.9	5.6	127.3	4.0	131.4	10.0	129.9
APR	6.6	131.2	15.0	130.5	6.6	127.8	8.5	132.6	43.0	131.0
MAY	6.5	130.5	43.0	122.2	6.4	128.0	12.0	129.2	46.0	131.7
JUN	8.0	128.8	94.0	125.7	7.7	129.1	20.0	126.8	50.0	131.2
JUL	11.0	126.8	119.0	122.4	10.7	127.3	32.0	126.8	35.0	128.7
AUG	19.0	125.0	130.0	124.5	31.5	126.2	47.0	122.5	35.0	127.8
SEP	26.0	116.9	140.0	125.5	38.0	126.9	56.0	120.2	44.0	128.0
OCT	65.0	123.9	360.0	122.4	46.0	128.1	13.0	110.2	55.0	128.0
NOV	144.0	125.8	1140.0	117.0	1.2	124.7	52.0	120.4	62.0	130.0
DEC	410.0	125.8	1880.0	116.5	1.5	132.2	2.0	130.6	64.0	130.0

Table 4: HPC ANALYSIS WITH THE INTRODUCTION OF ACT-1

17.10.1999	23:00	18.65	16.50	30.052	0.63	0.35	0.38	0.66	80.0	4 / 4	10.0	0.260	
24.10.1999	23:00	19.11	16.68	30.636	0.64	0.42	0.22	0.65	82.0	3 / 3	6.0	0.276	
31.10.1999	23:00	18.20	16.40	29.532	0.63	0.42	0.21	0.63	102.0	7 / 6	5.0	0.278	
07.11.1999	23:00	18.19	16.08	29.301	0.66	0.43	0.23	0.61	71.0	6 / 6	3.0	0.271	
14.11.1999	23:00	18.54	16.03	29.617	0.65	0.40	0.25	0.58	103.0	2 / 2	7.0	0.286	
21.11.1999	23:00	18.42	16.90	30.098	0.66	0.42	0.24	0.57	98.0	4 / 3	8.0	0.287	
28.11.1999	23:00	18.72	15.66	29.541	0.66	0.42	0.24	0.55	100.0	3 / 2.5	7.0	0.298	
05.12.1999	23:00	19.06	15.82	29.992	0.65	0.41	0.24	0.52	90.0	5 / 5	8.0	0.298	
12.12.1999	23:00	18.74	16.62	30.224	0.67	0.42	0.25	0.50	93.0	3 / 3	16.0	0.300	
19.12.1999	23:00	19.21	15.32	29.796	0.66	0.42	0.24	0.49	96.0	3.5 / 2.5	14.0	0.337	
26.12.1999	23:00	19.54	15.28	30.098	0.66	0.43	0.23	0.46	98.0	5 / 4	16.0	0.302	
02.01.2000	1:30	18.53	16.11	29.662	0.66	0.41	0.25	0.55	82.0	6 / 6	10.0	0.332	
09.01.2000	23:00	18.65	17.10	30.466	0.65	0.41	4.24	0.43	80.0	3 / 3	14.0	0.328	
16.01.2000	22:30	19.58	15.62	30.373	0.58	0.33	0.25	0.42	71.0	4.7 / 5	29.0	0.351	
23.01.2000	23:00	19.31	16.72	30.863	0.59	0.35	0.24	0.40	69.0	5 / 4	17.0	0.379	
			SHUT DOWN										
13.02.2000	23:00	20.91	15.87	31.876	0.74	0.66	0.08	0.30	85.00	6 / 6	40.0	0.260	
20.02.2000	23:00	20.90	15.96	31.928	0.74	0.32	0.42	0.27	90.0	4 / 3	37.0	0.370	
27.02.2000	23:30	20.88	16.07	31.984	0.76	0.43	0.33	0.24	81.0	3 / 3	26.0	0.373	
05.03.2000	22:30	20.89	15.89	31.870	0.75	0.42	0.33	0.23	75.0	4 / 4	21.0	0.342	
12.03.2000	23:00	20.71	15.75	31.593	0.74	0.46	0.28	0.21	76.0	4 / 5	19.0	0.390	
19.03.2000	23:30	20.51	16.54	31.939	0.74	0.47	0.27	0.20	78.0	4 / 4	18.0	0.406	
26.03.2000	22:30	20.66	16.59	32.124	0.74	0.48	0.26	0.20	77.00	4 / 4	16.0	0.436	
02.04.2000	23:00	20.17	15.91	31.164	0.68	0.44	0.24	0.19	82.0	4 / 3.5	30.0	0.437	
09.04.2000	22:30	20.60	16.71	32.147	0.70	0.44	0.26	0.18	79.0	4 / 3	28.0	0.497	
16.04.2000	22:30	20.24	16.13	31.386	0.68	0.44	0.24	0.17	81.0	2.5 / 3	29.0	0.500	
23.04.2000	22:30	20.51	16.02	31.580	0.65	0.41	0.24	0.17	90.0	3.5 / 3	20.0	0.485	
30.04.2000	23:00	20.25	16.68	31.776	0.65	0.40	0.25	0.15	92.0	3 / 3	18.0	0.478	
07.05.2000	23:00	20.33	15.86	31.289	0.42	0.22	0.20	0.14	230.0	4 / 4	14.0	0.497	
14.05.2000	23:00	19.80	15.03	30.186	0.89	0.32	0.57	0.12	87.0	1.5 / 1.5	116.0	0.355	
21.05.2000	23:00	19.87	15.52	30.594	0.90	0.45	0.45	0.10	80.0	3 / 3	92.0	0.341	

3.4 Other problems experienced in CO₂ removal unit

Corrosion on 14x10" Reducer:

On 06.05.2000, one year after starting using ACT-1, dissolved iron in HPC solution was 90ppm. But since beginning of the month of May 2000, some sludge formation was found in both the mechanical filters which were chocking frequently - on 7th May 2000, the iron in HPC solution jumped to 230 ppm. 3000 Kgs of fresh Vanadium was immediately added.

On 8th of May 2000 we had a leak in the HPC line to HPC absorber, on the reducer 14" x 10" down stream of the flow control valve.

Plant was shut down and reducer was removed. It was found having a hole with 4.0 mm opening at the outside and with smooth and cupped internal cavity of approx. 30 mm dia from the inside caused by erosion/gouging. A new 14" x 10" reducer was fabricated in the workshop and installed. The CO₂ removal unit was lined up after a re-oxidation.

After this incident a planned wall thickness at critical selected locations was carried out. No significant loss of wall thickness was measured at any of the above inspected locations. UOP however have recommended to replace some of the elbows/reducers at critical location prime to high velocity, to avoid unforeseen failure.

In T/A 2001, 3 reducers and one tee were replaced using stainless steel material. In the T/A 2004 we have planned to replace most of the reducers and elbows subject to high velocity, using stainless steel.

LP Boiler Tubes Leakage:

On 15/04/1997 the H₂ slippage in CO₂ which was at 0.8% started rising, reaching 1.5% by 18/05/1997. The increase was gradual and there was no fluctuations as experienced earlier during foaming.

The LP Boiler was suspected having tube leakage. H₂ was also detected at the bottom of regenerator tower.

A local vent on the shell side was opened to release some of the hydrogen. When vent opened, the hydrogen in the CO₂ came down to 1%.

Plant was kept running till we had an opportunity of unplanned shut down on 24th May 1997. During inspection of the LP Boiler, trans-granular cracks were observed in 3 tubes. The inspection report indicates that the failures are due to SCC. The exchanger had again tube leak in 2000 and two tubes were plugged. In 2001 T/A further eight tubes were plugged.

It was decided to replace the LP Boiler by another exchanger and upgrade material from AISI 304L to Duplex Stainless Steel. The new LP Boiler capacity is 10% more and the new exchanger will be installed in the next T/A.

3. CONCLUSION

- The sustained efforts to improve the performance of Benfield CO₂ Removal Unit combined with the measures taken in other sections and equipments reflected in general increase of the plant load and in improving the reliability of the ammonia plant (As shown in Tables 5 and 6).
- Ammonia plant is now running at 132% capacity without undergoing any major debottlenecking.
- Even though being located in an energy rich Gulf region, FERTIL is conscious of the importance of energy and is committed to its optimum usage. The energy consumption of its ammonia plant is consistently lower than the design of 9.4 Gcal/MT and the average value is now 9.0 Gcal/MT which is better than the world average of 9.2 Gcal/MT of similar plants as pointed out through a benchmarking survey.

Table 5: Ammonia Plant Achievement Indices From 1995 to 2003

Year	Actual Production MT	Capacity Utilisation (%)	On-Stream Factor (%)	Production Rate (%)	No. of S/Ds	S/D Days	T/A Days
1995	441219	120.88	99.019	122.08	3	3.58	Nil
1996	402943	110.09	88.48	124.43	6	42.16	27.94
1997	453121	124.14	99.356	124.95	2	2.35	Nil
1998	403639	110.59	91.132	121.35	6	32.27	27.1
1999	463076	126.87	100	126.87	Nil	Nil	Nil
2000	423605	115.74	92.933	124.54	5	25.865	Nil
2001	437208	119.78	93.38	128.28	2	24.17	23
2002	442730	121.30	96.03	126.31	3	14.5	Nil
2003	473,987	129.9	99.89	130.0	1	0.4	Nil

Table 6: Highest Monthly Rate Of Production

Month	Jan 1997	Jan 1998	Mar 1999	Apr 2000	Feb 2001	Jan 2002	Jan 2003
Rate of production	125%	128.3%	130.8%	130.5%	131.2%	133%	132.5%