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Analysis of Production Loss in Ammonia and Urea Plants during 2017-2020

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Abstract

Continuous operation is important for ammonia and urea plants for achieving high on stream and energy efficiency. Plant operation could be affected due to both internal and external problems. The internal or plant related problems could be due to mechanical, instrumentation, electrical, process and other reasons. The external problems can be shortage of raw materials, non-availability of utilities, labour issues and adverse market conditions. In order to assess the reliability of plant operation, FAI has been carrying out the downtime analysis of ammonia and urea plants every three years. Data on planned and forced shutdown due to various reasons are collected and detailed plant section-wise analysis is carried out. The present article gives the analysis for the period of April 2017 to March 2020 for 29 ammonia and 30 urea plants. These plants achieved on-stream days of 329.4 days for ammonia and 325.5 days for urea. There has been an increase in mechanical problems resulting in lower on-stream days compared to previous three years' period. The production loss on account of factors external to the plants were also significant during the period. There was loss of production of about 2.0 million tonnes (Mts) ammonia and 3.6 Mts urea for the entire survey period.

Key words : Ammonia plant, urea plant, downtime, shutdown, reliability, on-stream days; mechanical, electrical & instrumentation problems

1. Introduction

Continuous operation of process plant is dependent on reliable operation of plant & equipment and availability of resources. Any breakdown can cause significant losses of production and efficiency. Given the large size of plants, this in turn results in huge operating losses. There may be occasions when plant has to take shutdown due to non-availability of raw materials, utilities, water and labour which are external to plants. Ammonia plants operate under severe conditions of temperature and pressure. Reliable operation of static and rotating equipment remains a challenge. In integrated ammonia-urea complex, urea plant is completely dependent on continuous operation of ammonia plant. Corrosive nature of ammonium carbamate, an intermediate during urea production, affects the life of equipment. Electrical, process and instrumentation problems also interrupt the continuous operation. FAI has been carrying out downtime survey since 1980s to analyse the events leading to forced shutdown of the plants (Swaminathan & Jain (1985); Nand (2000); Goswami et al. (2012, 2015 and 2018). The purpose of the analysis is to provide feedback to plant managements on type of problems encountered by various plants individually and lesson learnt can help in selection of materials of construction of equipment, design & layout of equipment, repair procedures, adoption of better maintenance and operation practices.

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The downtime analyses for 29 ammonia and 30 urea plants were carried out during the fertilizer year April 2017-March 2020. The data represent about 92% of ammonia and 90% of urea production during the period. The internal factors or plant related downtime is categorized as mechanical, electrical, process, instrumentation and other miscellaneous reasons. The external factors include shortage of raw materials, utilities like power and steam, water, problems due to labour and business related issues. Section-wise downtime for ammonia and urea plants have been carried out to identify specific equipment or process step causing downtime. The results have been compared with the past surveys.

2. Reporting Methodology

Downtime has been reported as average in down time days per plant per year (DDPY). Similarly, number of shutdown are reported as shutdown per plant per year (SPY). Planned turnaround, forced shutdown and on-stream days are reported as average of 3 years' period.

3. Ammonia Plant

Of the 29 ammonia plants studied, 28 have downstream urea plants. All the plants covered in the survey are operating on steam reforming process with natural gas as feedstock except one plant based on naphtha. **Table 1** presents the vintage and size of the plants. All the plants covered in the survey are operating for more than 20 years. Four plants based on fuel oil were converted to natural gas feedstock in 2013 by changing their front end. These ammonia plants have been categorized in the youngest plant category of less than 10 years. The size of ammonia plants varied from less than 600 to 2200 MTPD. A number of plants have undergone a series of de-bottlenecking exercise during the last 15 years.

Table 1. Characteristics of surveyed ammonia plants

Vintage		Size	
Years	**No.**	**MTPD**	**No.**
40 or more	6	≤600	4
>30 to ≤ 40	9	>600 to ≤ 900	3
> 20 to ≤ 30	10	>900 to ≤ 1500	9
10 to ≤ 20	-	>1500 to ≤ 2200	13
<10	4*		
Total	**29**	**Total**	**29**

Note : 28 plants are based on natural gas feedstock and 1 is based on naphtha

* Front end of plants converted to natural gas from fuel oil

3.1 Planned Turnaround

The average period for planned turnaround has been reducing continuously. It was 14.5 days for 2017-2020 period compared to 19.3 days during 2014-17 and 23.1 days during 2011-14. During previous surveys, longer turnaround days were observed due to revamp activities by some plants during 2014-17 and feedstock changeover in 4 fuel oil based plants during 2011-14. Plants are also adopting practices of turnaround once in two years. Due to pandemic, a few plants postponed the turnaround planned in March 2020 to next financial year. A few plants which had taken shutdown had to extend the turnaround due to lockdown.

3.2 Number of Shutdowns and Loss of Production

Tables 2 provides the number of shutdown, downtime in days for various reasons and the loss of production for all the three years. The number of shutdowns were 3.7 SPY during 2017-2020. These were the lowest of all the previous surveys. The number of shutdowns were 4.0 SPY for 2014-17, 6.1 SPY for 2011-14 and 6.3 SPY for 2008-11.

The longest period of continuous operation without any breakdown or planned turnaround achieved by a plant was 562.8 days. It was lower than 2014-17 period when a plant achieved operating days of 724 days without interruption. An average uninterrupted operation period was 287.5 days per plant which is longer than previous year's average of 263 days.

Forced downtime due to external as well as internal factors was 21.4 DDPY during 2017-2020. The corresponding loss in production due to forced downtime was more than 2.0 Mts of ammonia for the three years. There has been considerable increase in downtime from all the previous surveys. During 2011-14, average forced downtime was 15.0 DDPY while for 2014-17 it stands at 10.3 DDPY. About 72 per cent of forced downtime during the present survey was due to factors external to the plants. A few plants lost production due to disruption in power supply. One plant faced water supply problem which resulted in downtime of 113.2 days during the period. A plant faced manpower related problem in March 2020 after nationwide lockdown.

Table 2. Number of shutdown and forced downtime (2017-20)

S. No.	Category	Number of shutdown per plant per year	Forced downtime per plant per year	Loss of Production (tonnes)
1.	Plant related problems	2.69	6.0	674520
2.	Offsite and utilities	0.53	0.4	41293
3.	Shortage of raw materials	0.04	0.04	3110
4.	Labour problems	0.01	0.1	7860
5.	Water shortage	0.05	1.4	43015
6.	Others	0.42	13.5	1379475
	Overall	**3.74**	**21.4**	**2149273**

3.3 Plant Related Problems

The plant related downtime of 6.0 DDPY was same (6.0 DDPY) as in 2014-17 and but lower than 10.5 DDPY in 2011-14 period. **Table 3** gives the breakup of plant related problems as mechanical, electrical, process, instrumentation and others. Mechanical problems accounted for more than 87% of the plant related downtime. During 2017-2020, the downtime due to mechanical problems was higher at 4.3 DDPY compared to 4.6 DDPY in 2014-17. But it was lower than 7.8 DDPY recorded in 2011-14 period. Downtime due to electrical problems was 0.3 DDPY which was same as previous survey period. There was reduction in process and instrumentation related downtime compared to previous surveys.

Table 3. Downtime in ammonia plant due to plant related problems (DDPY)

S. No.	Reasons	2008-11	2011-14	2014-17	2017-20
1.	Mechanical	8.8	7.8	4.6	5.3
2.	Electrical	0.3	0.3	0.3	0.3
3.	Process	0.6	1.2	0.7	0.06
4.	Instrumentation	0.9	1.1	0.4	0.3
5.	Miscellaneous	0.0	0.2	0.03	0.07
	Total	**10.6**	**10.6**	**6.0**	**6.0**

3.3.1 Mechanical Problems

The section-wise details of mechanical problems are given in **Table 4**. The total downtime in all plants for 2017-20 was 428 days. Synloop and refrigeration accounted for about 34% downtime followed by reformers (both primary and secondary) as 26.1%, synthesis gas compressor (12.4%) and purification section (10.7%).

♦ *Desulphurization and reforming*

Only one plant reported downtime of about 8 days in desulphurization section. The downtime was caused due to failure of furnace coil of de-sulphurizer. Downtime in primary reforming was 67.4 days. One plant was shutdown for about 27 days for replacement of tubes and primary reformer catalyst. A plant reported downtime of about 6 days on account of damage of primary reformer tunnel during 2018-19. Five plants reported problem due to ID/FD fans mostly in the range of 1.4-4.0 days. Downtime of 4 days in a plant was due to high vibration level of ID fan turbine due to damaged side bearings. The damaged bearings were replaced. Another plant was shutdown due to ID fan clutch problem. The cause was continuous running at full speed due to combustion air pre-heater chocking problem. The plant replaced the combustion air-preheater and started periodic inspection of ID fan clutch. Other plants observed vibration in ID/FD fan which were resolved by changing the bearings.

Downtime for secondary reformer was 44.6 days of which 34.3 days' downtime were due to leakages in boiler tubes in Waste Heat Boilers (WHBs) in 4 plants. One of the plants faced problem of primary waste heat boiler tube leakage on two occasions in 2017-18 and 2018-19 contributing 6.8 and 12.7 days to downtime, respectively. Another plant reported downtime of 5.9 days due to tube leakage in WHB. Process gas leak, from WHB bypass flange leading to fire, was reported by another plant. A plant faced tube leakage from 2 numbers in super heater steam drum and these were plugged. One plant reported 4.4 days' downtime due to trim heater dome flange leakage. The gasket was replaced, bolt tightened and steam sparger arrangement was made to minimize the chances of fire hazard.

A plant reported shutdown of about 7.7 days due to high differential pressure across secondary reformer due to fusion of top portion of catalyst. The catalyst was unloaded, sieved and loaded back. The shortfall quantity was filled with spare catalyst. After replacement, differential pressure came down from 2.3 to 0.44 kg cm^{-2}.

♦ *Gas purification*

Purification section, included the shift reactors, carbon dioxide removal and methanation. No downtime was observed in high temperature shift section. Low temperature shift and methanation accounted for downtime of 3.2 days and 0.4 days, respectively. Major downtime of about 37 days was observed in

Table 4. Mechanical failure downtime in ammonia plants (based on reforming process)

Major Sections	2008-11 (26 plants)		2011-14 (27 plants)		2014-17 (27 plants)		2017-2020 (29 plants)	
	Days	%	Days	%	Days	%	Days	%
1. Pre-treatment Section	1.2	0.2	0.0	0.0	8.0	1.9	8.0	1.9
2. Pre-reformer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3. Primary reformer	84.3	14.9	63.9	10.4	29.7	7.3	67.5	15.8
4. Secondary reformer	122.5	21.6	91.8	14.9	51.0	12.5	44.6	10.4
5. Purification	59.4	10.5	148.6	24.2	93.7	22.9	45.8	10.7
6. Synloop & Refrigeration	78.0	13.8	157.6	25.6	108.3	26.5	147.4	34.4
7. Syngas Compressor	76.4	13.5	96.0	15.6	37.6	9.2	53.2	12.4
8. Other Compressors & Turbines	92.3	16.3	44.6	7.2	33.9	8.3	33.2	7.8
9. MiscellaneousMajor Equipments	52.5	9.3	12.8	2.1	46.8	11.4	28.4	6.6
Total	566.6	100.0	615.3	100.0	409.0	100.0	428.1	100.0

carbon dioxide (CO_2) removal section. A plant faced problem on four occasions contributing downtime of 21.8 days. Reasons for downtime were breakage of absorber level control valve's stem, leakage through valve body on GV solution line going to absorber, absorber level control valve plug damage due to erosion and carbon dioxide process gas reboiler tube failure causing lower CO_2 purity. As remedial measure, new stem and plug were installed, valve replaced with spool piece, actuator replaced with a bigger actuator and damaged tubes of reboiler were plugged. In another plant, reboiler tube leakage on four occasions led to total downtime time of about 12 days during the period. The leaky tubes were plugged and plant was restarted. The same plant was under forced shutdown for about a day for attending HP regenerator top leakage job.

♦ *Synloop and Refrigeration*

In synloop and refrigeration section, out of total downtime of 147.4 days, about 40% was due to reactor, 43% due to exchangers, about 13% due to waste heat boilers and rest due to other miscellanceous reasons.. Sudden leak at synthesis converter gas outlet nozzle contributed downtime of 20.3 days in one plant. Another plant faced problems in S-50 reactor every year of the period. These problems included leakage in the converter outer lines, welding joint leakage of pressure differential tapping at converter inlet line and leakage in electric heater top flange. Flange bolts were tightened and gas of top main cover was replaced. A back-end shutdown was undertaken due to fire because of weld joint leak. Another plant noticed weld crack in ammonia converter (S-50) shell. The ammonia converter was bypassed for reliability and safety of the plant. The converter will be replaced with the new one. Yet another plant also reported converter effluent cooler tube leakage.

♦ *Syngas, Refrigeration and Recycle Compressors*

Eleven plants faced downtime due to problems in synthesis gas compressor resulting in downtime of 53.1 days of which 34 days were due to compressor problems and rest were due to drive. The synthesis turbine tripped due to high axial displacement in a plant leading to downtime of 5.6 days. The plant replaced the rotor. Another plant faced downtime of 8 days due to high vibration in turbine. The plant overhauled the turbine to resolve the problem. An ammonia plant synthesis gas compressor was tripped due to sudden malfunction of its governer system and steam turbine hydraulic HP/LP valves leading to fluctuation in RPM. Due to this disturbance, CO_2 process gas inlet Pressure Safety Valve (PSV) popped. Downtime of about 2.4 days was reported. To repair the PSV, complete shutdown of the plant was taken. The plant carried out the overhauling of the governing system and rotor of turbine in the subsequent annual turnaround. The same plant faced another problem of tripping of synthesis gas turbine due to fluctuation in RPM. Upon restart and subsequent inspection, turbine LP servomotor was found to be faulty. The same was repaired and machine was restarted. Some other plants faced downtime of less than a day for replacement of seal of 2nd barrel due to higher seal drain rate, tripping due to governer oil low pressure and replacement of 1st & 2nd stage barrel seals.

The tube leakage in 3rd stage intercooler caused downtime of 4.5 days in one plant. Tripping of synthesis gas compressor due to high radial vibration resulted in downtime of 12.5 days in another plant. Synthesis gas compressor's high vibrations in the 1st barrel caused downtime of about 4.5 days in a plant. The 1st barrel was opened and carried out alignment thus rectified the problem. Another plant faced problems of almost 2.5 days on three occasions. On two occasions, plant was stopped due to high vibrations and on one occasion for suction strainer inspection.

In a unique configuration, a plant operates two gas engines to drive syngas, air, recycle and refrigeration compressors. The gas engine tripped due to turbocharger failure on two occasions and once stopped due to air line leakage. The total downtime of 3.9 days was reported.

No downtime was reported in recycle compressor.

Refrigeration compressor downtime was 18.9 days for the period faced by 3 plants. One of the plants had 14.8 days of downtime due to sudden tripping due to high radial vibrations in HP case both drive and non-drive ends. The reasons for high vibrations were damage of HP case bearing and dry gas seal which were replaced. Another plant faced back-end trip due to governer hunting resulting downtime of a few hours.

♦ *Miscellaneous Causes*

Miscellaneous reasons caused 28.42 days' downtime. A plant faced downtime of 10 days to attend damaged molecular seal of flare stack. Heavy leakage on boiler feed water (BFW) discharge line caused downtime of 13.3 days in another plant. Downtime of about 3 days was faced by a plant due to leakage in cooling water header of ammonia plant.

3.3.2 Electrical Problems

About 5% of plant related downtime was due to electrical problems. A plant was tripped due to short-circuiting by a peacock and tripping of synthesis compressor. The other reasons reported by the plant are tripping of all LT motors, control cable damage, flash over in electrical substation, tripping of synthesis gas compressor on high exhaust pressure due to tripping of hotwell pumps as a result of electrical fault, failure of 100 DC supply, tripping of GV section circulation pump due to 3.3 kV feeder tripping while starting CDR blower, power limitation due to GTG unloading and power failure owing to direct power supply fuse away during hooking up UPS. A plant reported tripping due to flash over resulting failure of 11 kV breaker and tripping of GT-C twice. As a corrective measure, regular vacuum cleaning of the panel internals, replacement/repair of defective components, sealing against pest and breaker maintenance are carried out. The existing ventilation system was made more effective to reduce dust/ moisture intake into the substation and periodic ultrasonic checks were started. About 7.2 days of downtime reported by another plant due to severe power dip, tripping of process air compressor hotwell pump and stand by pump did not start due to flash in 415 V power control panel and tripping of semi lean solution pump due to flash in 11 kV switch board bus of arc fault circuit protection (AFCP). It also faced flash in 11 kV switch board bus of AFCP. As a preventive measure, incomer feeder compartment sealing job was done. Cleaning frequency of filter of air handling unit increased and provisions made to ensure that there is no ingress of ambient air with high humidity. Dehumidifier was installed at electrical substation. In another plant, a motor operated valve in process gas line to CO_2 absorber inlet got closed due to malfunction leading to stoppage of the downstream sections. The electronic card of the motor operated valve was replaced in consultation with vendor and plant was restarted.

3.3.3 Instrumentation Problems

Instrumentation related problems accounted for 5.8% of total downtime days during the 2017-20 period. Most plants faced problems in instrumentation resulting low downtime. Failure of electronic governer of synthesis gas compressor caused downtime of 3.5 days in a plant. The failed actuator was replaced with a mechanical actuator. In one plant, secondary reformer tripped due to closing of air compressor turbine main steam valve consequent to failure of 110 V power supply to field instrument. In the second event, ammonia plant back-end tripped due to tripping of methanator on account of semi-lean pump discharge solenoid valve tubing failure which resulted in low semi-lean flow. Back-end of ammonia plant was shutdown due to tripping of refrigeration compressor turbine on account of control oil solenoid valve (SOV) instrument air tubing failure. A plant tripped due to malfunctioning of process air compressor (PAC) anti-surge control system and to make system healthy the anti-surge loop was configured in DCS. The back-end in the same plant was tripped due to synthesis gas control oil solenoid failure which was replaced. Another plant took shutdown of the back-end due to ammonia refrigeration compressor over speed due to malfunction of over speed protection system. The over speed protection system was replaced with new speed probes and amplifiers. Back-end tripped due to synthesis gas compressor HP seal oil overhead tank very low level switch malfunction. The switch was replaced and new tapping to be provided for 2/3 voting to increase reliability and availability. The same plant faced another problem of backend trip due to synthesis gas compressor recycle stage suction solenoid valve failure. The solenoid valve was replaced and coil resistances are being measured as and when opportunity comes. On critical valves 2/2 solenoid valve voting to be provided.

About a day's shutdown was faced by a plant due to tripping of synthesis booster compressor because of high hotwall level. This was resulting from choking of both suction strainers and pumps and IS -1 operated on low S/C ratio due to sluggish operation of 100 to 40 kg cm^{-2} steam let down valve. The let down valve operation was rectified by clearing the strainer chocking. Downtime of 1.4 days was faced in a plant due to false actuation of high vibration switch leading to tripping of synthesis gas compressor. Subsequently, primary reformer also tripped due to disturbance in steam header pressure caused by synthesis compressor trip and malfunction of KS to HS let down valve. Vibration probe connection systems were tightened and KS to HS let down system was repaired. Another plant faced shutdown for 1.85 days when process air compressor tripped on extraction/wheel chamber deviation being high and high vibrations. The governer was replaced and auto extraction was disabled. Yet another plant faced downtime due to partial trip of synthesis gas compressor on account of malfunction of 1st stage suction pressure indication. PT switch replaced and later 2 out of 3 logic implemented in ATR.

Some other problems encountered by the ammonia plants were:

- closing of primary reformer fuel gas USV due to solenoid failure,
- IS-1 actuated owing to ID fan turbine tripping,
- tripping of ammonia plant due to ID fan tripping because of TTV solenoid fuse problem.
- hydrogenator natural gas inlet USV's fuse was blown due to wire short circuit of its solenoid which caused tripping of primary reformer.
- tripping of ammonia plant due to actuation of IS-4 owing to low level in 2nd regenerator in GV section.
- tripping of methanation due to rising methanation temperature owing to high CO_2 slip from GV gas because of low flow to absorber due to chocking in absorber inlet valve.
- actuation of IS-2 because of problem in functioning of GCV of gas turbine drive of PAC.
- methanator inlet valve diaphragm leakage.
- ammonia converter inlet valve sudden closing.
- malfunction of level transmitter leading to very low level in process gas waste heat boiler.
- absorber exit MOV leak and also absorber lean solution inlet flow control valve (solenoid) failure.
- tripping of process air compressor due to :
  - opening of blow off valve.
  - high shaft vibrations in HP compressor due to sudden opening of valve (HV-35) on 40 ata steam header to ammonia plant and resulted in IS-2 actuation.
  - LP side radial vibration high false alarm followed by trip of GT-HRU and resulted in ýactuation of IS-2&IS-1.
  - PAC-GT tripping on first out indication of compressor inlet thermocouples disagree.
  - Problem in governing system due to malfunction of I/H converter and actuation of trip low-low pressure switch.
- tripping of Synthesis Gas Compressor due to :
  - seal oil tank level low resulted in 1S-7 actuation.
  - high vibration in LP compressor which needed proximeter replacement.
  - LP compressor vibration communication card problem.
  - high exhaust pressure due to condenser level transmitter failure (431-LIC-15).
  - PLC communication problem subsequently primary reformer tripped on actuation of IS -1 on low S/C ratio.
  - actuation of (PSLL-84) lube oil low-low pressure switch (Governer of main oil pump turbine replaced).
  - breaking of 3rd barrel seal oil tubing manifold of seal oil local indicator causing heavy seal oil leak from it.
  - anti-surge PLC power module failure.
  - valve out of run alarm generated due to faulty limit switch of make-up gas discharge valve.
  - "governor initiated shutdown" trip actuation.
- Backend shutdown due to refrigeration compressor problem and expander tripped due to solenoid failure.

3.3.4 Process related Problems

Process related problems were only 4.9 days during the entire period of survey. A day's downtime was reported in a plant due to tripping of aMDEA CO_2 section followed by complete back-end tripping. The tripping was due to sudden low level in LP flash column.

4 On-stream Efficiency in Ammonia Plants

The average on-stream days for three-year period of 329.4 days were lower compared to 335.7 days during 2014-17 but higher than 327.3 days during 2011-14. Main reason for lower on-stream days was longer downtime due to financial constraints in three plants. The average on-stream efficiency improved to 339.8 days excluding these plants. On-stream efficiency can also be represented as operating factor which is percentage of operating days in a year and is calculated as follows:

Operating factor = (On-stream days/365) x 100%

Factors which are beyond control of plant management and planned turnaround have to be excluded while considering the availability and reliability of the plants. The service factor provides an indicator of plant's availability which is calculated by excluding the business related downtime or external downtime.

Service factor = (On-stream days /365-business related downtime) x 100%

Reliability factor can be derived by deducting business related downtime and planned turnaround days from the denominator.

Reliability factor = (On-stream days/365-business related downtime-planned turnaround days) x 100%

Table 5 presents the operating, service and reliability factors for three survey periods. The operating factor for ammonia plants was lower than previous survey on account of lower on-stream days. The service factor was higher and reliability factor was same as previous survey period.

Table 5. Operating, service and reliability factors in ammonia plants given in per cent

Factors	2008-11	2011-14	2014-17	2017-2020
Operating	90.4	89.6	91.9	90.2
Service	92.1	90.7	93.0	94.2
Reliability	96.9	96.9	98.2	98.2

It can be seen that reliability of the plant increased since 2008-11 period and had reached a high level of 98.2% in 2014-17 which is maintained even in the latest period in spite of ageing of plants.

5. Urea Plants

5.1 Planned Turnaround

The average planned turnaround days were the lowest in this survey. During 2017-20, average planned turnaround days was 15.7 days compared to 17.5 days during 2014-17 and 22.0 days during 2011-14.

5.2 Number of Shutdown and Loss of Production

Table 6 presents the number of shutdowns, downtime and loss of production. The number of shutdown was 7.7 SPY with downtime days of 24.1 SPY. Plant related downtime was 4.26 DDPY and downtime due to external problems to plant was 14.47 DDPY. The reasons for external problems as explained in ammonia plants was due to financial constraints in three plants. The loss of production of urea for the entire survey period was 3.6 Mts or 1.2 Mts per year. This is equivalent to production capacity of a modern day plant.

Table 6. Reasons for loss of production in urea plants during 2017-20

Sl. No.	Category	No. of Shutdown (SPY)	Downtime (DDPY)	Loss of Production (tonnes)
1	Plant related problems	3.94	4.3	715567
2	Offsite and utilities	1.16	0.7	117912
3	Shortage of raw materials	1.69	4.5	601355
4.	Labour problems	0.01	0.1	8365
5.	Water problem	0.08	0.1	3231
6.	Other reasons	0.82	14.4	2157711
	Total	**7.70**	**24.1**	**3604141**

5.3 Plant Related Downtime

Plant related downtime increased to 4.3 DDPY for the period 2017-20 from 3.5 DDPY during 2014-17 as shown in **Table 7**. This was lower than 2011-14 period which was 4.6 DDPY. Mechanical problems were also higher than previous years' period and accounted for more than 80% forced downtime. Electrical, process and instrumentation related problems contributed 0.7 DDPY.

Table 7. Details of downtime in urea plants due to plant related problems in DDPY

Reasons	2008-11	2011-14	2014-17	2017-20
Mechanical	6.9	3.4	2.9	3.6
Electrical	0.3	0.4	0.3	0.3
Process	0.4	0.3	0.1	0.2
Instrumentation	0.3	0.3	0.2	0.2
Miscellaneous	0.3	0.3	0.03	0.01
Total	**8.1**	**4.6**	**3.5**	**4.3**

5.4 Mechanical Problems

The mechanical problems accounted for 3.6 DDPY. **Table 8** provides the section-wise mechanical failures in urea plants for three survey periods. Major downtime was due to problems in reactor which contributed 39.4% to total downtime followed by heat exchangers which accounted for 18.6%, decomposer/stripper problems 11.3% and CO_2 compressor problems about 6% of total downtime.

♦ *Synthesis and Recovery Sections*

Reactor problems have increased from the last two survey periods. Fourteen plants faced problems in reactors mainly due to leakages in reactor liner. A plant had preponed the annual turnaround each year of the period to attend reactor leak. Other typical problems faced by plants in reactor are rupture of urea reactor outer shell, neck liner leakage, man hole cover leakage, outer shell leakage, urea reactor pressure valve sensing line leak and weep hole leak near top man way neck portion.

The heat exchanger problem faced by 8 plants contributed to 55.7 days of downtime. The carbamate

Table 8. Details of downtime due to mechanical failures in urea plants

Equipment items	2008-11	2011-14	2014-17	2017-20
1. Ammonia pre-heater	0.00	0.03	0.11	0.00
2. Ammonia pumps	0.09	0.10	0.01	0.04
3. Carbamate pump	0.02	0.03	0.03	0.05
4. Slurry & other pumps	0.03	0.06	0.00	0.03
5. CO_2 compressor	0.45	0.51	0.78	0.21
6. Autoclave/reactor	2.73	0.48	0.45	1.41
7. Heat exchangers	0.88	0.78	0.58	0.66
8. Decomposer/stripper	0.91	0.67	0.45	0.40
9. NH_3/CO_2 recovery column	0.00	0.00	0.00	0.00
10. Absorber/recovery vessels	0.18	0.11	0.00	0.00
11. Evaporator/crystalliser	0.00	0.00	0.02	0.02
12. Centrifuge	0.00	0.00	0.04	0.06
13. Steam ejector/vacuum generator	0.01	0.00	0.01	0.00
14. Dryer/cooler	0.02	0.02	0.00	0.13
15. Blower/fan	0.01	0.09	0.00	0.05
16. Conveyer/elevator	0.06	0.02	0.05	0.03
17. Prill tower	0.06	0.08	0.08	0.04
18. Piping/valves	0.16	0.28	0.21	0.12
19. Miscellaneous	1.19	0.08	0.04	0.31
Total	**6.80**	**3.35**	**2.86**	**3.57**

condenser leakage problem was faced by 7 plants. Of the 55.7 days, about 44 % was contributed by one plant based on total recycle process due to problem in its partial condenser and distiller in each year of the survey period.

The decomposer and stripper sections contributed 33.8 days to mechanical failures. Problems such as leakages from flange of HP stripper off gas line, HP system temperature indicator nozzle, tube/tube sheet in HP stripper and stripper vapour line thermowell were observed. Shutdown due to sight glass leakages in MP decomposer and LP decomposer, leakage from upstream flange of I/V of top safety valve of HP decomposer and replacement of HP decomposer top dome gasket were mentioned by some plants.

♦ *Carbon dioxide compressor*

The CO_2 compressor in 17 plants contributed 17.7 days of downtime of which 9.1 days was due to drive problems and 8.6 days due to compressor. A plant faced problems in HP case labyrinth seal thrust bearing and high vibration at rear side due to carbon deposition on gland seal. The downtime of 5.4 days was faced. The plant replaced the labyrinth seal and cleaned oil gland seal to resolve the problem. Drive side problems occurred due to high radial vibrations, problem in HP control valve of turbine, hunting in LP lift valve, hunting due to coupling damage and low suction pressure. The compressor side problems in other plants include high thrust bearing temperature in HP case, high vibrations, fire in compressor house and final discharge pressure safety valve weld joint leakage.

In reciprocating type, CO_2 compressors, downtime was reported due to rider ring failure, inspection of suction strainer of 2nd stage booster compressor, inspection and replacement of rings and valves of cylinder.

♦ *Pumps*

Downtime due to ammonia, carbamate, slurry and recirculation pumps was 9.8 days. Four plants faced problems in ammonia pumps, two in slurry pumps and one plant faced tripping in recirculation pump.

♦ *Prilling Tower*

A plant faced scrapper damage problem which resulted in downtime of 2.6 days in a natural draft prilling tower. Problems in induced/forced draft prilling towers included damage of coupling of melter agitator cycloreducer. A plant faced downtime of about 11 days due to fluidized bed cooler repairing job.

♦ *Other causes*

Miscellaneous reasons accounted for about 26 days of downtime. A plant was under shutdown in 2017-18 for about 9 days as about 1 ft crack was developed on the heat affected zone near 3rd circumferential welding of ammonia receiver vessel. The old weld was removed and welding was done after grinding. A shutdown was taken by the same plant in 2018-19 to attend leakage of about 3" length at 3rd circumferential seam welding at the top of ammonia receiver vessel. Plate of 1 m x 1 m was replaced and welded. Later shutdown was taken for replacement of ammonia receiver vessel. This resulted in downtime of about 10 days during 2018-19.

5.5 Electrical, Instrumentation, Process and other Problems

The urea plants faced problems of about 24 days' due electrical, 20 days due to process and about 16 days due to instrumentation.

5.5.1 Electrical Problems

Some typical electrical problems resulted in downtime in urea plants are as under:

- flash in urea motor control centre (MCC).
- CO_2 compressor electrical panel, urea substation incomer breaker relay failure-relay replaced.
- 11 kV bus flash over due to corona effect-panel internals were cleaned and replaced/repaired.
- ammonia pump tripped on VFD card failure
- fan motor bearing damage
- CFD blower motor burnt out
- tripping of cooling water pump
- problem in urea incomer power supply
- power dip
- switchgear flashover
- tripping of GT due to generator high bearing vibration and electrical fault
- flash over in terminal box of transformer of GT
- load shedding due to 132 kV transformer failure in MRS
- boiler tripping due to flash occurred on 3.3 kV panel
- tripping of blower UGB 302 motor
- tripping due to severe power dip
- tripping due to flash in 11 kV electrical bus coupler in AFCP
- tripping due to restricted earth fault relay of transfer malfunction leading to trip of transformer
- short tripping during changeover of ammonia carbamate pump. High current drawn by motor and subsequent transformer tripped on overloading

5.5.2 Instrumentation Problems

A plant faced CO_2 compressor anti-surge valve seizure problem due to failure of air filter regulator to positioner, CO_2 compressor turbine HP lift E/H converter problem. Faulty E/H replaced. In another plant, CO_2 compressor unloaded due to anti-surge valve opening, plant shutdown for renewing anti-surge controller input cables. 3rd stage suction transmitter replaced with new one. Individual isolation provided for suction and discharge temperature by providing independent barriers instead of motor board setup. Grounding was done properly by connecting shield cables. Typical instrumentation problems in other plants leading to downtime were:

- problems in separator drum outlet valve
- reactor outlet valve repair of solution drain valve
- HPDR control valve out of order
- LDV at reactor top did not opened, operated on hand jack
- centrifugal carbamate pump inverter ECO Cord failure
- carbamate pump flow transmitter flange heavy leakage
- heavy leakage of CO_2 from tapping of final discharge pressure transmitter of CO_2 compressor
- plant tripped due to carbamate pump suction flow low, erratic level indication and replacement of CO_2 compressor anti-surge valve
- false actuation of extraction pressure high, switch calibrated and plant restarted
- CO_2 turbine got tripped due to malfunctioning of vibration relay card, electronic governer problem and failure of HP control valve CPC power

5.5.3 Process Related Problems

In a plant, CO_2 compressor turbine tripped on account of low CO_2 suction pressure caused by sudden foaming in MDEA section of ammonia plant. Another plant faced poor vacuum in 2nd stage due to leakage in E-15 elbow downstream inlet flange and polymer choking observed in ejector (EJ 6) and its connecting lines. Flange was tightened and ejectors were flushed for removing polymers. CO_2 compressor tripping occurred due to low suction pressure, tripping of lube oil pump leading, low cooling water flow and closing of MOV at reactor outlet. In a plant, slurry tube chocking caused vacuum problem in one stream of urea plant and booster pump deprime in another stream. This plant also faced cooling water low flow resulting in chocking of carbamate line feeding to reactor. A plant had to take shutdown due to high MP loop pressure due to low discharge pressure. Chocking problems faced in ammonia booster pumps discharge strainer, urea melt return line from prill diverting valve to urea solution tank, scrubbers and crystallizers slurry circulation pump.

6. On-stream Efficiency in Urea Plants

The on-stream days in urea plants were lower at 325.5 days during 2017-20 compared to 332.9 days in 2014-17 and 328.9 days in 2011-17. The plant operating, service and reliability factors for three survey periods are given in **Table 9**. The operating factor in 2017-2020 was lower due to closure of some plants for part of the survey period. The service factor is higher as the external factors were responsible for lower on-stream days. The reliability of the urea plant remains high but somewhat lower than 2014-17 on account of increase in the plant related downtime.

Table 9. Operating, service and reliability factors in urea plants in per cent

Factors	2008-11	2011-14	2014-17	2017-2020
Operating	88.6	90.0	91.1	89.1
Service	92.1	92.5	94.1	94.3
Reliability	97.8	98.6	99.0	98.7

7. Conclusion

The downtime in ammonia and urea plants for the 2017-2020 survey showed reduction in the planned turnaround days. There was an increase in forced downtime in ammonia and urea plants. This is reflected in lower average on-stream days of 329.4 days in ammonia plants and 325.5 days in urea plants during the survey period. This is the lowest of the last three surveys. Mechanical problems increased in both ammonia and urea plants and accounted for 87 and 83% of plant related downtime, respectively. Ammonia plants encountered problems in primary and secondary reformers, synloop boiler and CO_2 removal system. The rotating equipment such as synthesis gas, air and refrigeration compressors also contributed to significant downtime. Most of the urea plants faced problems in reactor, carbamate condenser, stripper, decomposers, strippers and CO_2 compressors. A higher downtime was faced by some plants in other equipment such as prill tower scrapper, ammonia receiver vessel, cooler, and blowers. The contribution of electrical, process and instrumentation problems were low but affected a large number of plants. The study has highlighted the areas/equipment which caused significant downtime. There are lessons to be learnt by plant managements from each other to make operation of these critical plant more reliable and safe.

A few plants faced business related downtime higher than previous periods. Though the operating factor remain lower but service and reliability factors remained high for both ammonia and urea plants. This indicates that plant management are able to ensure high reliability and availability in spite of ageing of plants. This has been possible due to preventive maintenance and replacement of old equipment. The study also shows that various breakdowns were handled very efficiently limiting downtime to bare minimum. Low operating factor was caused by business related issues beyond control of plant management.

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