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Experience of Non-Condensible Gases Handling System in Andhra Paper Limited


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Abstract: ***The sulphur in the cooking process can result in bad odour in the surroundings of a Kraft Pulp Mill. Together with the odour, sulphur compounds can also be an environmental problem since they are released into the atmosphere. Community odour concerns are an ongoing issue for many in the Pulp and Paper industry and a continuing part of most mill environmental management programs.***

This paper describes the concept of Non-Condensible Gas and APL NCG Handling system & its experiences as a case study.

Introduction

Kraft pulp mills are characterized by their unique foul odour that is due to mainly for reduced sulphur compounds also referred as Non-Condensable Gases that are generated in the digester and other areas of the recovery cycle (i.e., evaporators, dissolving tanks, lime kiln, etc). The Andhra Paper Limited produces bleached chemical pulp from hardwood like Subabul, Eucalyptus & Casuarina with kraft process where Non Condensable Gases are also generated as a byproduct.

NCG Definition

In the Kraft process, white liquor is used for pulp cooking. Sulfide present in the White liquor in the form of Na_2S reacts with the inorganics & organic compounds present in the wood and releases the NCGs. NCG is what remains after the gases, generated during the pulping process, have been cooled and the heavier components have condensed to liquid. The malodorous gases typically found in a kraft pulp mill are:

- Hydrogen Sulfide H_2S
- Methyl Mercaptan CH_3SH
- Dimethyl Sulfide $(CH_3)_2S$
- Dimethyl Disulfide $(CH_3)_2S_2$

Methyl Mercaptan and Dimethyl Sulfide are formed during cooking when methoxyl groups of lignin react with HS-(Hydosulphide ion). The vapours containing above mentioned sulfur compounds generated in the Kraft liquor cycle collectively known as Non-Condensible Gases, or NCG. Basically, the gases are: Total Reduced Sulfur (TRS) gases, Turpentine, Methanol, Nitrogen, Oxygen, and water vapor. Although the term NCG includes turpentine, methanol, and water vapor, these components are in fact condensible. TRS gases, nitrogen, and oxygen do not condense into the liquid state. The total reduced sulfur gases are total sulfur compounds that are resulted from reduction of sulfur. These gases are of vary bad odour (pungent smell), highly toxic, corrosive, and explosive/flammable within a certain concentration range when mixed with air. These properties can be described as under.

NCG Are Explosive and Flammable: -

The explosive and flammable nature of NCG will discuss in the following figures:-

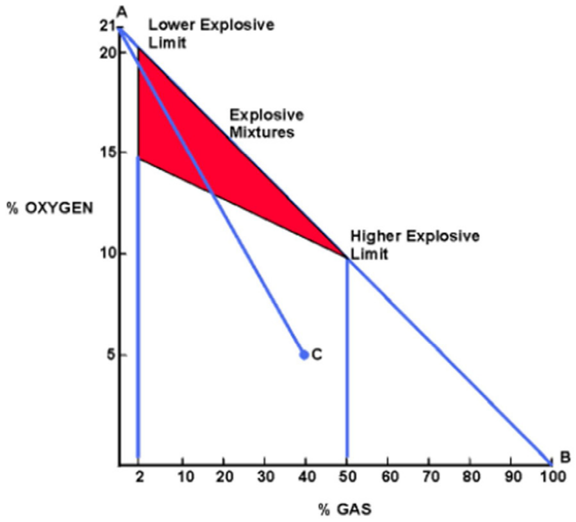

Fig-1 (NCG Explosive Range)

As shown in the above graph, the TRS gases are explosive when mixed with air within a range of 2% to 50% concentration. When the TRS concentration in the mix becomes above 50%, the available Oxygen is less and is insufficient for the explosion. Hence, any percentage of TRS gases between 2 to 50% in air is an explosive mixture.

The details of the explosion Limit of TRS gases are given as follows:

EXPLOSION LIMITS				
NCG COMPONENT	LEL (% V)	UPL (% V)	FLAME SPEED (mts/sec)	AUTO IGNITION TEMP (^0C)
HYDROGEN SULFIDE	4.3	45.0		260.0
METHYL MERCAPTAN	3.9	21.8	0.54	340.0
DIMETHYL SULFIDE	2.2	19.7		206.0
DIMETHYL DISULFIDE	1.1	8.0		300.0
TURPENTINE	0.8	6.0	152.40	252.7
METHANOL	6.7	36.5	0.45	463.8
TRS (COMBINED GASES)	2.0	50.0	0.60	
Explosive Ranges are dependent on the percent oxygen in CNCG mixture				

Table-1 (TRS Gases Explosive Limits)

NCG Are Toxic

Hydrogen sulfide (H_2S) is very toxic in nature. At 20 ppm (parts per million) it causes irritation of the eyes and respiratory tract. Thirty minutes of exposure at 500 ppm causes severe sickness and at 1,000 ppm thirty minutes of exposure can cause death. The other TRS gases and turpentine are also very toxic. Thus the NCG is highly toxic.

NCG Are Corrosive

Non-condensible gases are highly corrosive to carbon steel. These gases are normally saturated with water and condensation occurs in the collection system. Some of the TRS gases, especially hydrogen sulfide (H_2S) and methyl mercaptan (CH_3SH), are acidic and the combination of acidic condensate and the oxygen present in the NCG can be very corrosive to carbon steel. Other components of NCG, especially turpentine and methanol, are very strong solvents and can dissolve or soften plastics or resin in the fiberglass reinforced plastic piping. Stainless steel has proven to be corrosion resistant to NCG and is the preferred material of construction for NCG collection systems.

Types of NCG System:

There are many sources of NCG in the pulp mill. Some sources emit a small gas volume with high concentrations of NCG, while others have large volumes with low concentrations. Based on concentration and volume, NCG generation is an integrated Pulp and Paper unit classified as HVLC & LVHC.

1. High Volume Low Concentration (HVLC) :

A HVLC stream is simply a stream of air contaminated by TRS and organics. HVLC stream are normally dilute and nonflammable at the point of collection. This allows HVLC streams to be safely transported as dilute mixture. Examples of HVLC NCG Sources : Washer Hood, Miscellaneous storage tank vents, etc. The first and most important characteristic of HVLC gases is that the concentration of components in these streams falls well below the lower explosion limits (LEL). Still, the TRS compounds present are noxious and have a very low threshold of odour detectability, resulting in the need for their collection and disposal.

2. Low Volume High Concentration (LVHC) :

A LVHC stream is rich in total reduce sulfur (TRS) and organics. LVHC sources will be collected and maintained as a concentrated streams. Example of LVHC NCG Sources: Evaporator area, Foul Condensate tank, etc.

In addition to the above two, the foul condensate generated during the pulping and black liquor evaporation process also emit odor because of the presence of TRS compounds. Foul Condensate Sources: Evaporator, HVLC & LVHC drain.

The NCG handling system 1st of its kind started in APL in 2002 and was upgraded from time to time as described below.

Sr. No	Descriptions	Year
1	LVHC System commissioning	2002
2	HVLC System commissioning by M/s Enmas Andritz Private Limited	2007
3	LVHC System upgradation by Lundberg	2015
4	Foul Condensate & NCG System study by Lundberg	2015
5	Foul Condensate system commissioning	2015
5	HVLC System up-gradation (Modification of WBL Tanks gas collection by Lundberg)	2018

Table-2 (APL NCG System Upgradation details)

HVLC Collection and firing system at APL

From all the source points HVLC gases are collected and gas stream is taken into scrubber to reduce the condensate as well as liquid methanol by scrubbing with cooling water. After that, the scrubbed gas from the scrubber enters to spray tower middle section through an interconnecting line. The spray tower is having baffles so that there is a good heat transfer between cooling water and HVLC gases. The circulation pump circulates water through a plate-type heat exchanger where the circulated water temperature is dropped. The cooled-down HVLC gases are released out of the spray tower after passing through demister pads of the spray tower top to remove any carryover droplets of water. The gas outlet from the spray tower is connected to the blower suction. The blower discharge passes through a droplet separator and further connected to another blower. This blower discharge is connected to a NCG heater and from the heater, the HVLC gas goes through a flow meter and further to the Recovery boiler tertiary airport burning. Number of condensate drain lines are provided in main line on pipe rack to recovery boiler to minimize the moisture in the gas taken to boiler.

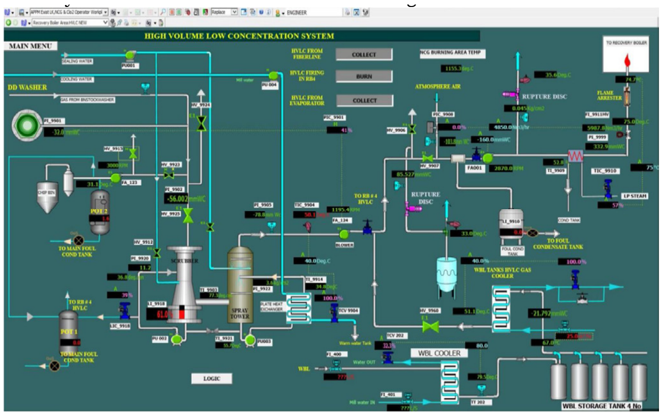

Fig-2 (APL HVLC system)

LVHC Collection and firing system at APL

The LVHC NCG from each source is routed to the collection header via the vent/collect valves. All of the sources have an automatic shutoff valve, vent valve, rupture disc, and flame arrester. Additionally, an interlock system is included to vent the respective source during abnormal situations. The combined gas flow then travels to the steam ejector suction. The steam ejector is used to send the LVHC NCG through the piping to the lime kilns by forcing 3.75 kg/cm^2 motive steam through a restricted nozzle. The flow of steam creates a vacuum on the suction line. The LVHC NCG transitions from the vacuum at the suction to pressurized flow from the ejector outlet. The LVHC NCG then passes through an NCG flow meter to monitor and ensure that a safe minimum line velocity is always maintained, to protect the system against burn back events at the incineration points. The LVHC NCG is then routed to either Lime Kiln No. 1 or Lime Kiln No. 2 for injection and incineration of the LVHC NCG gases. A rupture disc is provided at the incineration points in the NCG piping to protect piping and equipment from over-pressurization. A signal from a pressure transmitter installed near the rupture disc will alert operators to excessive pressure in the NCG line and the possibility of disc rupture. Rupture discs must be replaced after rupturing.

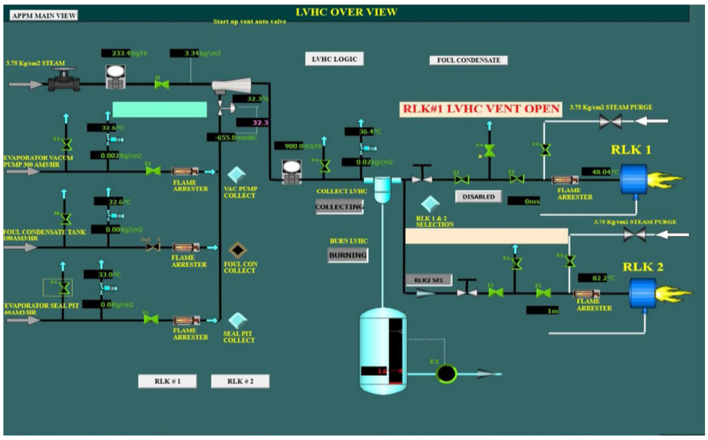

Fig-3 (APL LVHC System)

Foul Condensate Collection system at APL

All foul condensate collects from different points and is stored in collect pots. After that from these pots, it transfers to the main foul condensate tank. Before foul condensate is sent to ETP, its treated with Hydrogen peroxide.

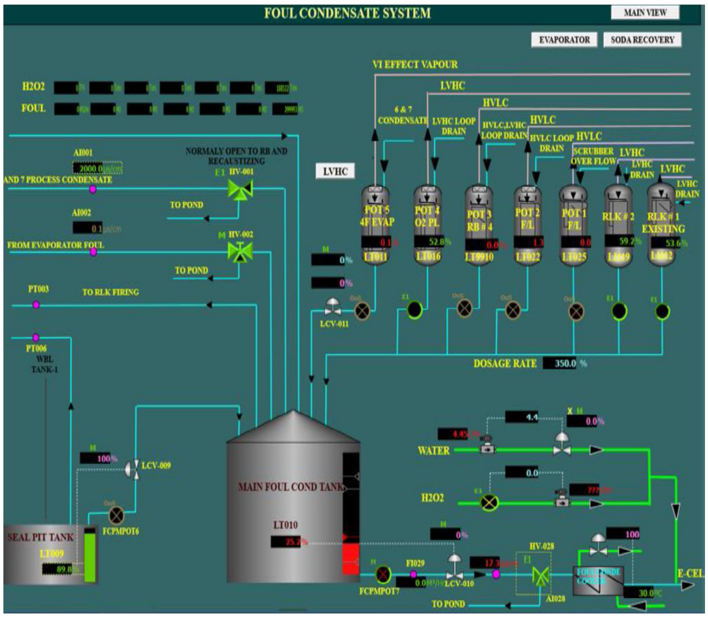

Fig-4(APL Foul Condensate System)

Volume of NCG generated at different sources
(As per Design of NCG System)

LVHC NCG System (High percentage of NCG)	
NCG Sources:-	
Evaporate Vaccum Pump	300 Am³/hr at 54 deg C
Foul Condensate main Tank	100 Am³/hr at 59 deg C
Evaporator Seal Pit	60 Am³/hr at 54 deg C
Total to Ejector (At RLK)	460 Am³/hr at 55 deg C

HVLC NCG System (Low percentage of NCG)	
NCG Sources:-	
Chip Bin Gases	1800 m³/hr at 54 deg C
Fiber Line	6500 m³/hr at 88 deg C (Including Digester & ODL Blow tank)
WBL Tank	400 m³/hr at 88 deg C
Total to Blower (At RB-4)	~3500m³/hr less than 55 deg C

 # Note:-

1. Total volume of NCG generate at Fiber Line = ~8600m³/hr
2. Volume of NCG after processing at Fiber Line = ~ 3200m3/hr.
3. Chip Bin gases generate = ~1800m³/hr (Present chip bin gases continue vent out after reduce the gas temperature by chip bin cooler).
4. Digester blow tank & ODL blow tank gases are continue vent out now.

Fig-5 (APL NCG Generation Details)

Monitoring of NCG Operations:

At APL, all these NCG are collected & Processed by NCG operation system. NCG Processing system consists of collection, processing of gases, transportation to Recovery Boiler / Lime Kiln, Incineration of the gases. The NCG handling process is also monitored through DCS (The distributed control system) display with start/stop positions, running lights, alarm annunciators, etc. is used by the desk engineers to supervise and control the system. Safety interlocks protect the system during upsets. All required safety precaution taken while collecting, handling & transportation and also at Incineration stage of the NCG which can be explained as follow:

Process Safety Equipment:

1-Flame Arresters:

The flame arresters prevent flame propagation through the systems in the unlikely event that accidental ignition should occur. Our HVLC NCG system has One flame arrester located at the firing point of the recovery boiler. In the case of LVHC NCG system has five flame arresters which are located at each source point (three nos) and near the incineration point at the lime kiln (two nos).

2-Rupture Discs:

Rupture discs prevent pipeline damage during transportation in the event of a rapid pressure increase in the system. In APL, LVHC & HVLV NCG systems both have rupture discs installed in parallel to vent valves to relieve the gas if the vent valve fails to open.

3-Pressure/Vacuum Relief Valves

The NCG system is equipped pressure/vacuum relief valves, which are located at the evaporator vacuum pump seal pit and foul condensate main tank to prevent the system from unwanted pressure/vacuum.

4-Steam Ejectors

Steam ejectors rather than blowers are used for transporting the LVHC gas streams. This eliminates all mechanical and other potential accidental ignition sources because of friction.

5-Steam Purge

The LVHC NCG system piping is equipped with steam purge connections for both incineration points. The piping to the incinerator is steam purged at startup and shut down. The purpose of the steam purge is to remove any stagnant gas or air from the system and at startup also serves to preheat.

6-Mist Eliminators

The mist eliminators serve to remove the contaminated condensate from the lines. This prevents any unwanted blast inside the Kiln because of the liquid condensate. The condensate from the mist eliminator at the lime kiln flows to the foul condensate pot covered under NCG system.

7- Auto Vent valves

Automatic emergency vents are located at all NCG source locations and at all incineration points. These vents are capable of automatic operation on the signal from the safety interlock system.

For a cleaner and safe environment, the NCG Handling system in APL follows **NCG Policy**. One dedicated Engineer has been deputed as NCG Coordinator who coordinate with all the source area, transportation as well as final incineration team in the Mill regarding NCG handling. He is reported to the Unit Head & this helps NCG system to get a focus from Top Authorities. Always, the below mentioned Don't are followed strictly through proper monitoring & follow up

Never Mix LVHC (concentrated NCG) & HVLC Gas (diluted NCG with probability of high oxygen). It possibly causes an explosive mixture.

Similarly, never allow air to mix with LVHC to prevent from explosion.

During Annual Outage, like other production system, the NCG systems are made shut, thorough inspection done and required preventive maintenances are carried out.

Further, any incident in NCG system is analyzed for Root Cause Failure Analysis & necessary actions planned & executed there by showing focus of management NCG handling.

APL Monthly NCG Activities Status Report: Every month NCG job activities & venting details report is generated and gaps are tracked for review of Unit Head.

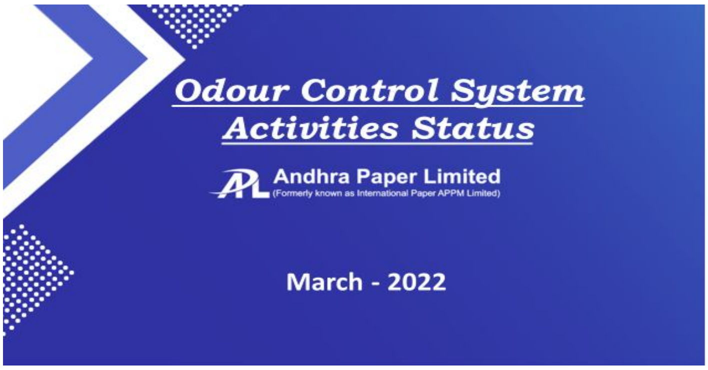

Fig-6 (APL NCG Report)

NCG Venting Details

Sr. No	Process Description	No of Times		Venting Hours		Volume of Gas Vented (M^3)	
		Apr'22	Up to Mar'23	Apr'22	Up to Mar'23	Apr'22	Up to Mar'23
(A)	HVLC	0	0	0	0	0	0
(B)	LVHC	0	0	0	0	0	0
(C)	Foul Condensate	0	0	0	0	0	0
(D)	Total	0	0	0	0	0	0

Fig-7 (APL NCG Report)

LVHC System Running Status

Sr No	Main Parameter Description	UoM	Norms	This month	Status
1	Steam flow to LVHC Ejector	Kg/hr	298	230 to 240	
2	LVHC ejector steam pressure	Kg/cm^2	3.75	3.1 to 3.5	
3	Pressure near LVHC Ejector	mmWC	-850	-730 to -740	
4	LVHC NCG flow to kiln	Am^3/hr	985	690 to 700	
5	NCG temperature near burner	^{0}C	85	82 to 83	
6	LVHC Venting Hours	Hrs	0	0	

Fig-8 (APL NCG Report)

HVLC System Running Status

Sr. No	Main Parameter Description	UoM	Norms	This month	Status
1	HVLC Pressure near sources (DD Washer, Filtrate tank)	mmWC	-10 to 25	-6 to 15	
2	Near RB4 main blower vaccum maintained	mmWC	-200 to -300	-110 to -130	
3	From spray tower F.C to PHE	^{0}C	85	40 - 55	
4	From PHE F.C to Spray tower	^{0}C	40	38 - 45	
5	Mill water to PHE	^{0}C	35	28 - 31	
6	Warm water from PHE	^{0}C	70	55 - 60	
7	HVLC gas temperature	^{0}C	45 to 50	30 - 28	
8	HVLC Venting hour	hour	0	0	
9	HVLC Flow	M^3/Hr	5000	3000 - 4000	

Fig-9 (APL NCG Report)

Foul Condensate System Running Status

Sr No	Main Parameter Description	UoM	Norms	This month	Status
1	All Foul Condensate Pot level	%	Min-25 / Max -70	Min-25 / Max -70	
2	H_2O_2 dosing to Foul Condensate	LPhr	As per requirement	15 - 21	
3	Foul Condensate flow to E-Cell	M^3/Hr	30 - 40	18 - 21	
4	Water for dilution in Foul Condensate line	LPH	80 - 100	40 - 50	
5	H_2S level near all Foul Condensate Pot, Pumps & surrounding area	ppm	0	0	
6	Foul Condensate main tank Pressure	mmWC	-50 to -150	-50 to -150	
7	Foul Condensate main tank surrounding area H_2S Level	ppm	0	0	

Fig-10 (APL NCG Report)

One such incident happened on Foul condensate tank. Analysis & RCFA made at that time is described below.

APL NCG Foul Condensate Tank Incident

In June 2016 some upgrades work going on near the main foul condensate tank area. On the morning of the incident, fabricating (welding and grinding) work of a new vessel immediately next to the foul condensate tank going on. Additionally, on the other side of the foul condensate tank, pipe was being pulled and installed for a plate and frame heat exchanger. There was a lot of activity occurring around the foul condensate tank at the time of the event. The foul condensate tank was at about 70% level of foul condensate. Foul condensate is composed mostly of water, but also contains flammable hydrocarbons. Under normal operations, the atmosphere in the tank does not contain enough oxygen to support combustion and is therefore not explosive.

Although some air in the vapor space of the foul condensate tank is normal, during the event, more air than usual found its way into the tank creating an explosive atmosphere. Air may have entered the vessel through the foul condensate tank seal loop or a leaking flange/manway or seal. The foul condensate tank seal loop did not have the required fill water line to ensure the loop is always filled with water. The vessel manway doesn't appear to be designed for a sealed tank and had inadequate seals. Improper design and seal may have also resulted in air leaking into the vessel. It is determined that the hot work activities likely ignited the contents of the foul condensate tank damaging the bottom and top of the tank. There was a small amount of air/oxygen that had entered the vessel. Once it was consumed, the explosion had stopped leaving the vessel intact. The foul condensate tank was the only part of the system that experienced the high pressure/explosion event. Typical safety features to relieve high pressure in the foul condensate tank were not designed properly to relieve vessel pressure. No one working around the tank was injured.

APL NCG measurement inside the plant & nearby area report

Environmental Laboratory
Certificate of Analysis

1. Sample Description : Odour parameters monitroing in the mill premisis and in the Rajamahendravaram.
2. Date of Monitoring : 13.06.2022
3. Monitoring Period : 02.00 PM to 05.30 PM
4. Date of Report : 13.06.2022
5. Monitroing Instrument : Phocheck Tiger VOC meter
6. Monitroing Conudcted by : M.Prakash Babu & G.Jayababu

S.No	Location	Measurement Time	Dimethyl Di sulphide, ppm	Methyl Mercaptan, ppm	Hydrogen Sulphide, ppm
1	North Gate Security	2:10 PM	BDL	BDL	0.0 - 0.1
2	Chipper House	2:13 PM	BDL	BDL	0.1-0.2
3	Katheru Road	2:18 PM	BDL	BDL	BDL
4	Mallayyapeta Road	2:22 PM	BDL	BDL	BDL
5	Wambay colony (Municipal dump yard)	2:29 PM	BDL	BDL	BDL
6	Quary Market	2:36 PM	BDL	BDL	BDL
7	Raja Theatre	2:41 PM	BDL	BDL	BDL
8	Kambala Tank (Vivekananda Statue)	2:47 PM	BDL	BDL	BDL
9	Y Junction - Indira Priya Darshini Park	2:51 PM	BDL	BDL	BDL
10	CTRI Junction	2:59 PM	BDL	BDL	BDL
11	TTD Kalyanamandapam gate	3:07 PM	BDL	BDL	BDL
12	Kotilingala ghat, (Chintalamma Ghat)	4:15 PM	BDL	BDL	BDL
13	Kotilingala ghat temple	4:23 PM	BDL	BDL	BDL
14	Kotilingala Peta, Ambedkar Statue	4:30 PM	BDL	BDL	BDL
15	Seetampeta X road	4:35 PM	BDL	BDL	BDL
16	Danvaipeta, Praksaham round park & Municipal school	3:15 PM	BDL	BDL	BDL
17	Hotel Shelton	3:23 PM	BDL	BDL	BDL
18	Road cum railway bridge 46/L pole	3:32 PM	BDL	BDL	BDL
19	Road cum railway bridge 135/L pole	3:40 PM	BDL	BDL	BDL
20	RMC entrance gate	3:55 PM	BDL	BDL	BDL
21	Methanol Storage area	4:42 PM	BDL	BDL	0.1 - 0.2
22	ClO2 Tank area	4:51 PM	BDL	BDL	0.2 - 0.3
23	DCS Road	4:59 PM	BDL	BDL	BDL
24	RLK Area	5:03 PM	BDL	BDL	0.1 - 0.3
25	4F & RB 4 inbetween	5:09 PM	BDL	BDL	0.2-0.3
26	CF6 Stack area	5:15 PM	BDL	BDL	0.2-0.4

Instrument Calibration Details :
Calibrated on : 18.06.2021
Calibration Due on : 17.06.2022

Remarks :
1. Dimethyl Disulphide is in the range BDL
2. Metyhyl Mercaptane is the the range BDL
3. Hydrogen sulphide is in the range of 0.0 to 0.4 ppm

BDL –Below detectable limit

Basic or Root Causes of the event:

Physical:

- Inadequate foul condensate tank protection
    - o Pressure/vacuum relief device designed for very small relief flow
    - o Seal loop depth was too deep
    - o Vent/collect station located 25 meters away
        - Rupture disc
        - High pressure interlock to vent the source
- Foul condensate tank and system design
    - o Incorrect man way design

Human:

- Excess work occurring around the foul condensate tank without proper safety precautions taken
    - o Welding and grinding on new vessel right next to foul condensate tank
    - o Fabrication yard right next to vessel
    - o Cutting, pulling, and welding pipe in pipe rack right next to the foul condensate tank
        - Forgetting to check seal loop to ensure seal loop is filled to prevent air ingress
        - Not checking areas of potential air ingress (flanges and manways) for leaks

Latent:

- Workers around vessel may not have been aware of the foul condensate tank and NCG piping due to no line labeling. With proper labelling of vessel and lines, mill workers may have been able to identify that the tank may contain an explosive atmosphere.
- No as-built P&IDs were generated of the foul condensate system

Fig- 11 (Foul condensate tank bottom damaged from incident lifting vessel off base)

Action was taken after the incident:

1- New pressure/ vaccum relief valve installed as per design.

2- In the seal loop continuous water system arrange.

3- Traning given to all personnel to improve awareness of NCG.

Conclusion: APL is located in the center of Rajahmundry. Being an Integrated Pulp & Paper Mill with Kraft process, it's very critical on the part of APL to maintain a clean and safe environment in the surrounding city. The NCG handling system of APL helped it to maintain it within the mill as well as its surroundings. With its unique focus on NCG handling & close follow up with required coordinators & reporting to Mill Manager helped APL to maintain a Clean & Safe environment in the Mill as well as in The Rajahmundry City.

References:

1. Collecting and burning Non-Condensable Gases, TAPPI
2. APL NCG reference Manual.
3. APL NCG Policy.