Chemical Engineering Research Bulletin 13 (2009) 25-28 Available online at http://www.banglajol.info/index.php/CERB

Processing of Carbon Disulfide at KRC for Safe Disposal

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Received 31 August 2009; received in revised form 4 October 2009

Abstract: The Karnaphuli Rayon Complex (KRC) was permanently closed down in January 1997 by leaving behind about 180 tons of Carbon Disulfide (CS_2) in sixteen storage tanks at various locations of KRC and CS_2 plant including in some vessels of CS_2 plant itself. An incineration facility was planned, designed, constructed, commissioned and operated to dispose all CS_2 left behind. The facility used some of the facilities of the closed Sulfuric Acid Plant (30 tpd) which was closed in December 2002. The incineration facility was commissioned on April 1, 2008 and the processing of CS_2 was completed on September 16, 2008. Catastrophic failure of the tanks was inevitable and matter of time. Such failure would have led to events worse than Bhopal causing deaths, fatal injuries and immediate environmental damage of all types. This is a success story of local engineering endeavor from laboratory to industry.

Keywords: *Carbon Disulfide, KRC, Incineration, Safe Disposal*

DOI:*10.3329/cerb.v13i1.3207*

1. Introduction

KRC went into commercial operation in 1967. This was built adjacent to the Karnaphuli Paper Mills Ltd. (KPM) to produce Rayon Filament Yarn (RF), Rayon Staple Fibre (RSF) and Cellophane. The complex consisted of plants, namely, RF (10 tpd), RSF (15 tpd), Cellophane (5tpd), Sodium Sulfate (15 tpd), Carbon Disulfide (10 tpd), Sulfuric Acid (30 tpd), Caustic Soda (17 tpd), Chlorine (15 tpd) and Hydrochloric Acid (10 tpd). The chlor-alkali plants and acid plants which had been in operation since 1953 as part of KPM were transferred to KRC's management with the operation of KRC.

The closure of KRC took places in stages. The productions of RF and Cellophane Paper were suspended in 1994. In July 1996, RSF production was suspended and the complex was declared permanently closed in January 1997. The CS_2 plant was closed on February 2, 1997 and the Sulfuric Acid Plant on December 15, 2002. KRC was closed down permanently by leaving about 180 tons of Carbon Disulfide in 16 tanks located at four locations of KRC site and CS_2 plant site. Some CS_2 was also left inside a number of vessels of the purification section of the CS_2 plant. After the closure KPM was entrusted to look after the KRC establishment.

KPM, thereafter, made efforts to dispose the stored CS_2 that include: sale of CS_2 abroad; venting CS_2 as vapor through RSF vacuum system; recovering sulfur from CS_2 by reacting with discarded clinker; production of products with CS_2 such as Carbon Tetrachloride, Potassium Ethyl Xanthate, Potassium Trithiocarbonate, Calcium Trithiocarbonate and Hydrogen sulfide (H_2S). All these efforts and suggestions did not produce any result.

In October 2004, Bangladesh Chemical Industries Corporation (BCIC) requested Bangladesh University of Engineering and Technology (BUET) for proposal for disposal of CS_2 with full responsibilities. The team from Chemical Engineering Department with the author as Team Leader submitted a proposal in March 2005 by considering three options and recommended the Controlled Incineration of CS_2 for its disposal. In August 2006, BCIC accepted the recommendation i.e. Controlled Incineration of CS_2 and in October 2006, KPM asked for complete technical proposal by assigning responsibilities such as engineering, procurement, supervision of construction, erection and testing, commissioning and monitoring. The proposal was submitted in April 2007.

The site preparation for the CS_2 incineration facility begun in May 2007 at the Sulfuric Acid Plant site. The construction of the facility begun in June 2007 and the facility was ready for commissioning in October 2007. The final inspection was completed on October 10-11, 2007.

The Department of Environment (DoE), Bangladesh in December 2007 issued conditional clearance by imposing additional responsibilities on the BUET team leading to change of the scope of work and services for the facility to be undertaken by BUET. The

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DoE issued the final clearance on March 16, 2008 for commissioning the facility.

The facility was commissioned on April 1, 2008 at 3.30 pm. The processing of all CS_2 in the sixteen tanks and the vessels of CS_2 plant was competed on September 16, 2008 at 5:30 pm.

Total quantity of CS_2 processed stands at 182.17 tons. The CS_2 was contaminated rendering it unsuitable for any chemical reaction without reprocessing including distillation.

The facility was commissioned, operated, maintained and decommissioned as per the procedures and instruction prepared by the team.

2. CS_2 Incineration Process and Design

The process basically consists of two steps:

a. Combustion of CS_2 with excess air in the presence of a natural gas (NG) flame.
$CS_2 + 3\,O_2$ (Air) = $CO_2 + 2\,SO_2$

b. The combustion products including those from natural gas burning after cooling are scrubbed with cold water in two packed towers arranged in series to remove SO_2 gas to the maximum extent possible involving the reactions:
$SO_2 + H_2O = H_2SO_3$
$CO_2 + H_2O = H_2CO_3$

The gases leaving the final tower consist of mainly N_2, O_2, water vapor, CO_2 and trace SO_2. The sulfurous acid bearing streams from the bottom of two scrubbers were discharged through two separate pipelines to the drain where these streams were mixed with a highly alkaline large stream being discharged by KPM. The resultant stream had reduced alkalinity and foaming.

The process flow diagram (PFD) of the incineration process is shown in Figure 1. The design of the facility was based on Single Conversion Single Absorption (SCSA) Sulfuric Acid Production process with permissible SO_2 emission through the stack of the final scrubber 10 kg SO_2 per ton of Sulfuric Acid Product (100% by weight). The facility was designed to process 120 l/hr or 152 kg/hr CS_2. A pilot plant was built and operated in the Chemical Engineering Department at BUET with the configuration same as the built facility to test and experience the operability of the process.

3. Equipment and Machinery for the Facility

The facility was built on the site of the closed Sulfuric Acid Plant by utilizing some of the equipment of the Acid Plant, namely, Sulfur Furnace, Waste Heat Boiler, Air Drying Tower, SO_3-Absorption Tower and Air Blower. These equipment were inspected, repaired and revamped to fit in the process. The Sulfur Furnace was modified to accommodate the natural gas burner and CS_2 burner. Equipment, Units and Items added to the facility included: CS_2 Day Tank and CC Dyke for the Day Tank, Auxiliary Tank for CS_2 Day Tank, Water Storage Tank by removing the Sulfur Melter, Pumps for supply water to scrubbers, Pumps for Day Tank for transferring CS_2 to CS_2 burner by displacing water, Air Filter, NG Burner System, New NG Pipelines, New pipelines for CS_2 connecting CS_2 Tank Yards and CS_2 Day Tank, New pipelines connecting different vessels/columns, Sulfurous Acid bearing pipelines, Repairing of Sulfuric Acid Plant structure, revamping control room, installing related instruments, control valves, flow meters, sensors and indicators, etc.

4. Fabrication Works, Erection and Construction

The workshop of KPM carried out necessary fabrication. The erection and construction of the facility were undertaken by KPM personnel and appointed contractors. The natural gas burners (Model: BG400 of M/S Bentone, Sweden) were supplied by Modern Erection Ltd. (MEL). The LDO burner was modified for use with CS_2.

5. Operation of the Facility

Hours used for actual processing of CS_2 was 3643.50 with an average hourly rate of 50 kg (39.68 litres). During the period from April 1, 2008 to September 16, 2008, the operation of the facility was interrupted 92 times for different reasons such as: CS_2 transfer to Day Tank (35), CS_2 Burner clogging (12), Natural Gas Burner Faults (31), Power (8), Water Supply (3), Natural Gas Supply Suspension (1), Repair and Maintenance (12), etc.

Interruptions caused 400 hours downtime of which interruptions due to CS_2 transfer to Day Tank were expected as normal as the full capacity of the Day Tank was 8 t CS_2. Tripping of the natural gas burner due to particulate matter arising from the contaminated CS_2 were unexpected surprises.

Personnel provided by KPM having operating and maintenance experience of the Sulfuric Acid and CS_2 plants to operate and maintain the facility proved equal to the task.

6. CS_2 Storage Tank

Only three storage tanks out of sixteen were found safe while the remaining thirteen tanks had become unsafe for various reasons including corrosion leading to cracks at joints, valve bodies and tank plates etc. Catastrophic failure of the tanks was inevitable and

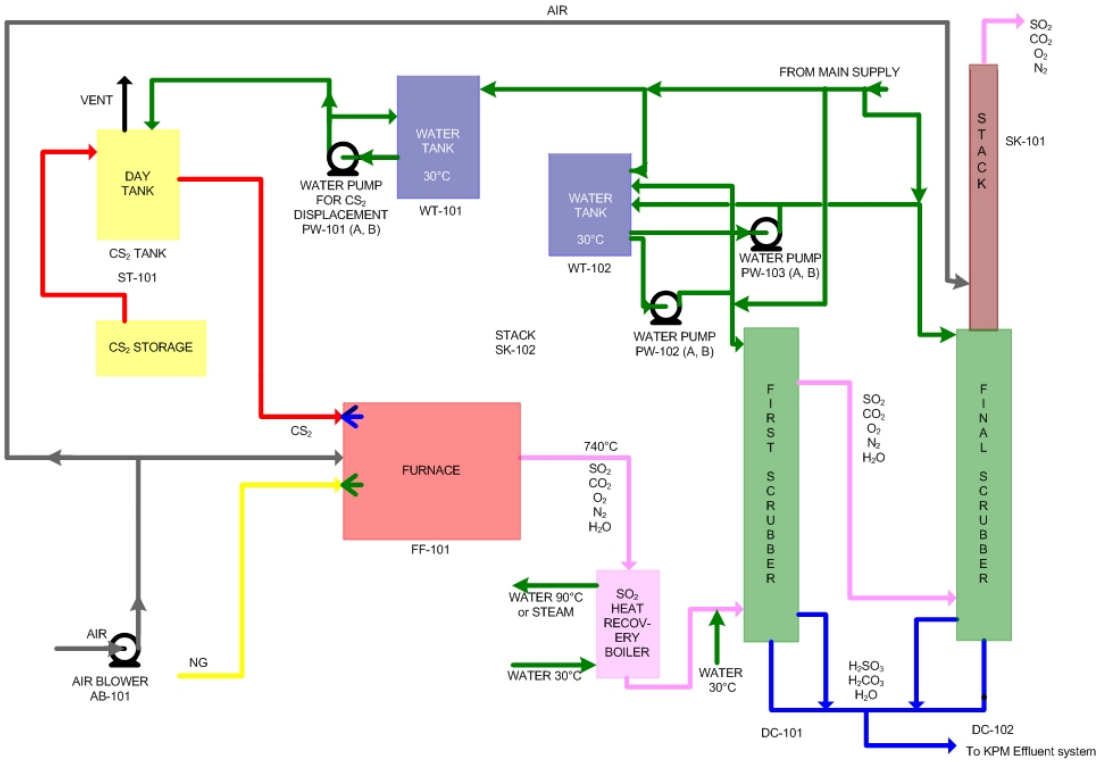

Figure 1: Process flow diagram (PFD) of the CS_2 incineration facility

matter of time. Such failure would have led to events worse than Bhopal causing deaths, fatal injuries and immediate environmental damage of all types.

7. Operation of the Facility below the Design Rate

After commissioning of the facility, it was operated at different CS_2 flow rates ranging from 30 l/hr to 150 l/hr with corresponding air flow rates to sulfur furnace form 1,200 Nm^3/hr to 2,700 Nm^3/hr for short periods to understand and evaluate the performance of various units of the facility. Considering the functioning of NG burner with air flow rate to the furnace, furnace temperature and CS_2 flame stability, stable operation of the waste heat boiler, pressure drops, stack plume under stagnant wind condition, height of the stack and impurities/contaminants in CS_2, it was decided to operate the facility at CS_2 flow rates 30-40 l/hr with air flowrates 1400-1600 Nm^3/hr and furnace temperatures around 500±10°C. Moreover, the Sulfur Furnace, Waste Heat Boiler, two Absorption Towers and Air Blowers being about 40 years old it was felt that at reduced CS_2 flow rate the safety of operation including control of SO_2 emissions during power failure and NG burner trip would be assured.

In stead of planned 84 days of operation of the facility, it took 137 days of operation to complete the processing of 182.17 t CS_2 against the estimated quantity of 180 t CS_2. This operating period includes 16 days equivalent of shutdown time. The most important thing to note that 182.17 t of CS_2 was processed smoothly without any incident and mishap during the operating period of 137 days.

8. Monitoring the Facility Operation

As required by DoE, Bangladesh, the BUET team measured SO_2 in the plant air and the stack plume touching the ground with Gastec Detector Tubes. The Quality Control Department of KPM measured SO_2 in the plant air, stack and plume touching the ground with Orsat Analyzer. The acidic effluents leaving the facility, mixed effluent (after mixing of acidic effluent and KPM alkaline effluent) and the downstream of the river Karnaphuli were monitored by measuring pH.

Relevant data on SO_2 in the plant air and pH of related streams were measured prior to the commissioning of the facility on April 1, 2008 and 24 hrs after the completion of incineration on September 17, 2008.

The emission of SO_2 inside the facility never exceeded the limits set by OSHA (Time Weighted Average: 5 ppm [13 mg/m^3]). The presence of SO_2 in the plant air in the operating areas was less than 0.10 ppm. The mixed liquid effluents had reduced alkalinity thereby improving the pH of the discharged stream to the river. There was marked reduction in foam formation in the river water from of the discharged efflu-

ent stream as noticed prior to mixing of acidic effluent streams.

The DoE, Bangladesh was provided with plant emission and effluent data regularly based on the reports prepared by the BUET team. Twelve such reports were submitted to the DoE through the Divisional Office at Chittagong including the one made 24 hrs after the completion of CS_2 processing.

9. Misgivings from Wrong Perception about Definition of Ambient Air

The DoE, Bangladesh has wrong perception with the ambient air definition used for Air Quality Standards. They have thus far failed to distinguish the Ambient Air Quality from the Plant Air Quality. Bangladesh does not have any standards or limits for gaseous emissions covering the Plant Air Quality. In its absence, the standards/limits by Occupational Safety and Health Agency(OSHA), National Institute for Occupational Safety and Health (NIOSH) and American Conference of Government and Industrial Hygienists (ACGIH) of USA were followed for workers exposure in Bangladesh, Table 1.

Table 1: US Standards for SO_2 concentration in plant air

	OSHA	NIOSH	ACGIH
TWA	5 ppm	2 ppm	2 ppm
STEL	-	5 ppm	5 ppm

TWA = Time Weighted Average; STEL=Short Term Exposure Limit

The Ambient Air Quality Standards are valid for the air outside the boundary of the industry or plant facility where the public has unrestricted access. There is a separate procedure by US EPA for proper placement of intakes for air sampler for the ambient air.

10. Decommissioning of Facility

The decommissioning of the facility started from September 17, 2008 after completion of processing of all CS_2 (182.17 t) following the decommissioning procedure. This was completed on September 30, 2008.

11. Cost for the Project

The total cost for completing the processing of 182.17 t CS_2 stands at about Tk. 12.70 million against the envisaged cost of Tk. 9.38 million given in the technical proposal. The final cost will be available after auditing of the accounts and adjustment of the amounts for the equipment and materials sent to store after decommissioning of the facility. The expected actual cost will be much lower than the present cost reported here above.

The cost over-runs for operating personnel and gas bills were due to the delay in issuing clearance by the DoE to commission the facility and the delay was as much as six months. Delay in procuring additional NG burner led to reduction in processing rate for about eight weeks and this resulted in extended operation of the facility by at least 15 days.

12. The Teams for the Task

The BUET team from the Chemical Engineering Department with Professor Quader as the team leader during the period 2004-2008 consisted of Dr. M.S. Islam, Dr. H.N. Mondal, Dr. D.A. Begum, Dr. M.A.A. S. Choudhury, M.M. Rahman, M.S. Islam, K.B. Kabir and I.A. Khan in different phases. The Coordinators from KPM in different phases of implementation were: Dr. K. Bhownik, Engr. Shekhar and M.A. Halim Bir Pratik, while Engr. Shekhar and M. Shahidul Islam supported the operation and maintenance of the facility throughout commissioning operation and decommissioning.