

BEFORE THE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI

IA NO. OF 2020

IN

ORIGINAL APPLICATION NO. 73 OF 2020

IN THE MATTER OF:

In Re: Gas Leak at LG Polymers Chemical Plant in RR Venkatapuram
Village in Andhra Pradesh

LG Polymers India Pvt Ltd.

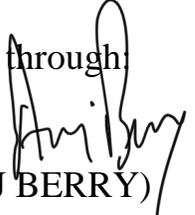
... Answering Respondent

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Filed through:


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PLACE: NEW DELHI

DATED: 09 November 2020

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BEFORE THE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI

IA NO. OF 2020

IN

ORIGINAL APPLICATION NO. 73 OF 2020

IN THE MATTER OF:

In Re: Gas Leak at LG Polymers Chemical Plant in RR Venkatapuram
Village in Andhra Pradesh

LG Polymers India Pvt Ltd.

... Answering Respondent

AFFIDAVIT ON BEHALF OF L.G. POLYMERS INDIA PRIVATE LIMITED TO PLACE ON RECORD ITS RESPONSES TO THE REPORTS DATED 17.05.2020 AND 28.05.2020 SUBMITTED BY THE COMMITTEE APPOINTED BY THIS TRIBUNAL VIDE ORDER DATED 08.05.2020

I, P. Arun Kumar, son of Mr. P. Bhaskar Rao, aged about 50 years, working as the Dy. Manager – Legal with L.G. Polymers India Private Limited having my office at R.R. Venkatapuram, Visakhapatnam – 530029, presently at Visakhapatnam, do hereby solemnly affirm and state as under:

1. That I am the Authorized Signatory of LG Polymers India Pvt. Ltd. ("LGPI"/ "Answering Respondent") and I am duly authorized to execute this affidavit on behalf of the Answering Respondent.

2. Vide order dated 29.10.2020 in Civil Appeal No. 2665 of 2020 and the Civil Appeal No. 2816 of 2020, the Hon'ble Supreme Court directed the Answering Respondent to file its responses to the report dated 17.05.2020 titled "*Interim Report of NGT Committee on Gas Leak of Styrene LG Polymers India Pvt Ltd*" ("Report 1") and the report dated



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28.05.2020 titled “*Report of the Joint Monitoring Committee constituted by the Hon’ble NGT, PB, New Delhi in OA No. 73 of 2020*” (“Report 2”) submitted by the six-member committee appointed by this Hon’ble Tribunal vide order dated 08.05.2020 (“NGT Committee”). A copy of the order dated 29.10.2020 issued by the Hon’ble Supreme court in Civil Appeal No. 2665 of 2020 and the Civil Appeal No. 2816 of 2020 is annexed herewith as **Annexure A**.

3. By way of the present affidavit, the Answering Respondent seeks to place on record its responses to the observations/ findings recorded in Report 1 and Report 2 on the basis of the records maintained by the Answering Respondent as also expert opinion and advice received by the Answering Respondent (“Reply”). The Answering Respondent is tendering the present Reply without prejudice to its submissions before the Hon’ble Supreme Court in Civil Appeal No. 2665 of 2020 and the Civil Appeal No. 2816 of 2020.
4. At the outset, the Answering Respondent denies all insinuations and conclusions that the NGT Committee arrived at in Report 1 and Report 2. As is elaborated below, the Answering Respondent submits that the Styrene vapour release from one of its tanks at the plant site was on account of the long and unprecedented storage of Styrene caused due to sudden stoppage of production on account of the government imposed lockdown on account of COVID-19 pandemic. The plant of the Answering Respondent is a continuous process industry and the Answering Respondent ought to have been permitted to run its plant during the lockdown period. In fact, the notifications issued by the Government of India (as elaborated below) did permit continuous process industries to operate, however, this permission was not granted to the Answering Respondent by the District Collector.
5. With a view to understand the causes and effects of the Styrene vapour release incident that occurred on the premises of the Answering



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Respondent on 07.05.2020 ("the Incident"), the Answering Respondent has availed the professional services of the following domain experts:

S No.	Name of the expert	Qualifications & details
1.	Dr. Harri Kytömaa [Group Vice President and Principal Engineer at Exponent, Inc]	Ph.D. from the California Institute of Technology; Fellow of the American Society of Mechanical Engineering; Was head of the Fluid Mechanics Laboratory and Associate Professor of Mechanical Engineering at the Massachusetts Institute of Technology.
2.	Dr. Michael Stern [Chemical Engineer, Thermal Sciences Practice – Exponent Inc]	Ph.D. in chemical engineering from the Massachusetts Institute of Technology; Licensed Professional Engineer in chemical engineering in two states in the United States.
3.	Dr. Rahul Nabar [Independent consultant in the chemical industry]	Ph.D. from the University of Wisconsin, Madison on applications of simulation techniques to selected problems in hydrocarbon (petroleum) processing; Adjunct Associate Professor at the Indian Institute of Technology, Bombay.
4.	Dr. Paul A. Nony [Principal Toxicologist and Director of Toxicology and Occupational Health at, CTEH, LLC]	Ph.D. in Interdisciplinary Toxicology from the University of Arkansas for Medical Sciences in Little Rock, Arkansas, USA; Certified in the comprehensive practice of industrial hygiene by the American Board of Industrial Hygiene (CIH #11135CP);



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		Certified Safety Professional (CSP #33934) as determined by the Board of Certified Safety Professionals; CTEH, LLC – Specializes in toxicology, human health risk assessment, industrial hygiene, indoor air quality, and chemical emergency response.
5.	Dr. Rakesh Dubey [Independent consultant]	Master of Philosophy degree in Chemistry and a Ph.D. in Chemistry; Ex-Director at the Disaster Management Institute (DMI), Government of Madhya Pradesh, Bhopal; Ex-Head of Branch at DMI for the management of chemical and industrial disasters.

These experts reviewed Report 1, Report 2 and other relevant material (including records maintained by Answering Respondent and undertook field visits & virtual tour of the plant premises) and within the limitations existing in view of the COVID-19 pandemic, provided the Answering Respondent with their expert opinion on responses to the observations / findings contained in Report 1 and Report 2 relevant to their area of expertise. The Answering Respondent's responses to the observations/ findings recorded in Report 1 and Report 2 in the present Reply are based on the expert opinion provided by the abovementioned experts. A copy of the profiles of the experts retained on behalf of the Answering Respondent are annexed herewith as **Annexure B**.

A copy of the opinion of the Dr. Harri Kytömaa (Exponent, Inc) and Dr. Michael Stern (Exponent, Inc) on the causes of the Incident and on the observations/ findings recorded in Report 1 and Report 2 is annexed herewith as **Annexure C**.



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A copy of the opinion of Dr. Rahul Nabar on the causes of the Incident and on the observations/ findings recorded in Report 1 and Report 2 is annexed herewith as **Annexure D**.

A copy of the opinion of Dr. Paul A. Nony (CTEH, LLC) on the effects of the Incident and on the observations/ findings recorded in Report 1 and Report 2 is annexed herewith as **Annexure E**.

A copy of the opinion of Dr. Rakesh Dubey on the effects of the Incident and on the observations/ findings recorded in Report 1 and Report 2 is annexed herewith as **Annexure F**.

6. Currently, owing to the COVID-19 limitations/ restrictions, the opinions of the experts received by the Answering Respondent are being annexed along with this Reply (at Annexure C to F). The Answering Respondent craves leave from this Hon'ble Tribunal to file these opinions by way of a notarized and/or apostilled affidavits at a later date, if required. The Answering Respondent also craves leave to file the documents/ material referred to or relied upon by the experts in their opinions, by way of an affidavit subsequently, if required. Separately, the Answering Respondent submits that these experts are available for any form of consultation / discussion with the NGT Committee and also will make themselves available for a cross examination if this Hon'ble Tribunal so deems necessary.
7. The following sections set out the brief background leading up to the Incident and the Answering Respondent's responses to observations/ findings of the NGT Committee recorded in Report 1 and Report 2. The Answering Respondent craves leave of this Hon'ble Tribunal to file a more detailed affidavit with responses to observations/ findings in Report 1 and Report 2, if necessary, at a later stage.



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1. BRIEF BACKGROUND OF LG POLYMERS INDIA PVT LTD

8. LG Polymers India Pvt Ltd, i.e. the Answering Respondent herein, is a company incorporated in India with its registered office at RR Venkatapuram Village, Pendurti Mandal, Vishakhapatnam, Andhra Pradesh - 530029. LG Chemicals India Pvt Ltd, being a company incorporated in India is the 100% holding company of the Answering Respondent. LG Chemicals India Pvt Ltd, a wholly owned subsidiary of LG Chemicals (South Korea) Ltd (a company incorporated in South Korea) acquired M/s. Hindustan Polymers Ltd in 1997, being a company engaged in manufacture of Polystyrene and Co-Polymers and renamed it as LG Polymers India Pvt Ltd, i.e. the Answering Respondent herein.

9. The plant (as described in detail below) and main corporate office of the Answering Respondent is located at RR Venkatapuram Village, Pendurti Mandal, Vishakhapatnam, Andhra Pradesh – 530029 (“Plant”), which is a part of a notified industrial zone by the Housing, Municipal Administration & Urban Development department, Visakhapatnam. The locality in which the Plant is situated was previously identified as a ‘heavy industrial zone’ as per G.O.Ms. No. 703 dated 29.08.1970 of Housing, Municipal Administration & Urban Development department, Visakhapatnam. However, subsequently, as per the 1st Master Plan approved vide G.O. Ms. No. 274 MA dated 23.05.1989, the lands surrounding the Plant were changed from ‘heavy industrial use’ to ‘residential use’ and the land in which Plant was located was earmarked as ‘industrial use’. Even as per the 2nd Master Plan approved vide G.O. Ms. No. 345 dated 30.06.2006, the land on which the Plant was earmarked as ‘general industrial zone’ and the surrounding lands were earmarked as ‘residential land use’. Consequently, there was a gradual increase in the residential occupations in the areas surrounding the Plant. A copy of the map depicting the Plant and surrounding areas along with photographs



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showing the development of residential units in the lands surrounding the Plant over a period of time are annexed herewith as **Annexure G**.

10. The Plant is spread over 217 acres of land. At the time of occurrence of the Incident, the Answering Respondent employed 275 persons and 370 contract labour.
11. The Answering Respondent is engaged in the manufacture of polystyrene products and engineering plastics compounds and all manufacturing activities are carried out at the Plant. The products manufactured are used for a wide range of end products ranging from writing pens, food packing material, electronic and home appliances such as refrigerators, televisions etc. The Answering Respondent is one of the top two manufacturer of these products with the other significant player in this industry being M/s Supreme Petrochem Ltd (having its manufacturing unit at Village Amdoshi, District Raigad, Maharashtra). The products manufactured by the Answering Respondent are mainly for consumption within India.

i. Manufacturing activities of Answering Respondent

12. Specifically, at the Answering Respondent's Plant, three main Polystyrene products, i.e. General Purpose Polystyrene (GPPS), High Impact Polystyrene (HIPS) & Expandable Polystyrene (EPS), are manufactured. The site also has a separate Engineering Plastics Compounding (EPC) plant. The Plant is divided into two parts: part 1, consisting of GPPS and EPS manufacturing units, EPC manufacturing unit as well as storage tanks M5 and M6 and part 2, consisting of HIPS manufacturing unit and two other storage tanks 111A and 111B. A copy of the map of premises of the Answering Respondent setting out the location and details about the manufacturing units and other offices within the premises is annexed herewith as **Annexure H**.



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13. Liquid Styrene Monomer (Styrene) is the key raw material used by the Answering Respondent for the purposes of the manufacturing Polystyrene products.
14. Styrene is not produced at the Plant. It is imported from South Korea and Saudi Arabia. The Answering Respondent requires approximately 11,000 MT of Styrene each month for the purposes of its manufacturing activities. As the Answering Respondent does not have a storage capacity for 11,000 MT at once at its manufacturing facility, generally shipments of Styrene are received in two separate installments per month. The import takes place through the port at Vishakhapatnam. The imported Styrene is stored in a leased transit terminal at M/s. East India Petroleum Ltd ("EIPL"). At the terminal of EIPL, there are two tanks ("Shore Tanks") for the purpose of storage of the imported Styrene by the Answering Respondent. At the Plant, there are four running tanks Tank M5(3300 MT), Tank M6 (2800 MT), Tank 111A (300 MT) and Tank 111B (300 MT) ("Storage Tanks") for the purpose of maintaining inventory of Styrene for manufacturing activities. During normal plant operations, Styrene is transferred from Shore Tanks to the Storage Tanks on a daily basis through road tankers.

ii. Styrene – characteristics, properties and details about Tank M6

15. The tank in question, Storage Tank M6, is an 18 meter diameter, 12.9 meter tall steel tank with an internally supported roof structure and a nominal liquid capacity of 3,100 m³ or 2,800 MT of Styrene. The tank was constructed per Indian Standard (IS) 803 in 1983 and post some upgradations, it is being used for storing Styrene since 2004. Tank M6 has a built-in insulation system that prevents the increase in temperature of the liquid due to atmospheric heat. Further, the tank, inter alia, contains a pressurized fire hydrant system around the tank including a medium velocity water spray system, a gas detection system in the bund wall, a pump unloading area, a foam pourer, breather valve and goose



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neck on the tank, a dedicated mobile foam tank of 100 liters, adequate lightning arresters and facility to continuously monitor tank temperatures through a centrally monitored control team with a 24 hour operator.

16. Styrene is a colourless liquid at room temperature with a flash point of 31°C and boiling point of 145°C. Styrene in storage has a tendency to auto-polymerise which is controlled by adding a small concentration of an inhibitor and by storing Styrene in ambient conditions. The most common inhibitor, and the one already present in the Styrene imported by the Answering Respondent, is para-tertiary butyl catechol (“TBC”).

iii. Protocol for storage of Styrene during normal operating conditions

17. The Storage Tanks at the Plant are running tanks. They are not intended to be used for storage of Styrene for long durations without regular deliveries and outflows, as operation without regular deliveries and outflows leads to stagnation. During normal operation, the running tanks receive multiple deliveries per day from tankers and are constantly discharging liquid Styrene to the manufacturing plants. Because of the constant additions and withdrawals, the material in the Storage Tanks is constantly mixed and refreshed with new material.
18. The Answering Respondent followed the following protocol for storing Styrene in Tank M6 during normal operations:

- a. The Answering Respondent continuously monitored the level of the tank through a level sensor connected to the facility’s central control system and through physical measurements via a dip hatch. The dip hatch is a 8 inch diameter opening in the roof of the tank in which a stainless steel measuring tape can be lowered into the tank to measure the liquid level.
- b. The Answering Respondent monitored the temperature of Styrene inside Tank M6 with temperature measurements at two

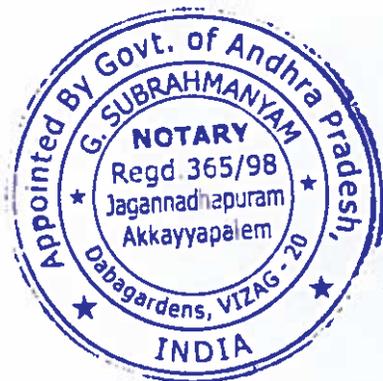


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elevations in the tank. At one location, the temperature was continuously monitored using a temperature sensor connected to the facility's central control system. At a second location, the Answering Respondent also monitored the incoming and outgoing temperatures of the Styrene from the chiller one or more times per day to monitor the performance of the refrigeration system.

- c. The Answering Respondent performs regular sampling of the Styrene in the Tank M6 to measure the concentration of inhibitor in the tank, the polymer levels in the Styrene and the color of the Styrene.
- d. While the Answering Respondent has a prescribed procedure for addition of TBC into the tanks, the TBC addition had not previously been necessary owing to the short residence times of Styrene in view of the continuous manufacturing operations. Also, the Styrene imported by the Answering Respondent already had TBC added in levels prescribed by the Answering Respondent.
- e. As Shore Tanks (where the imported Styrene is temporarily stored) do not possess refrigeration or insulation, Styrene is warm when it arrives at the onsite running Storage Tanks, Tanks M5 and M6. The warm Styrene from the Shore Tanks represented the greatest heat source into the tank by an order of magnitude when compared to heat from ambient warm air or sunlight. Accordingly, Tank M6 contains a refrigeration system that allows cooling of Styrene inside the tank. This process functions by extracting Styrene from bottom of the tank into a chiller and then throwing the same back into the tank. Tank M6 used a dip pipe arrangement for the refrigerated Styrene being returned. This design minimized the potential for static electric discharges (an ignition hazard) and also focused the refrigeration to the bottom of the tank where the tank received the warm styrene transported from the shore tanks. Further, the addition of



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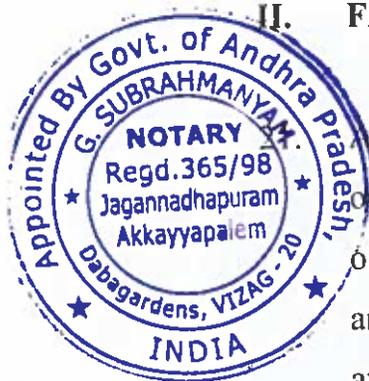
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warm Styrene, which has a lower density than colder Styrene, into the bottom of the tank creates mixing as the buoyancy of the warm Styrene stirs the tank.

19. In addition to the above protocols for onsite Storage Tanks, it is pertinent to note that the Shore Tanks used by the Answering Respondent, leased by EIPL to store the imported Styrene, do not possess insulation, refrigeration, or circulation facilities. As the Styrene stored at these Shore Tanks is ultimately used by the Answering Respondent, its quality is also of concern to the Answering Respondent. Therefore, during normal operations, the Answering Respondent used to ensure minimum residence time of Styrene in the Shore Tanks (2-3 weeks) through continuous manufacturing operations. Additionally, the Answering Respondent used to regularly monitor the Styrene temperature, TBC content, and polymer concentration.
20. Therefore, the methods deployed by the Answering Respondent for safe storage of Styrene and for prevention of auto-polymerisation were customary and they included combination of purchasing Styrene with sufficient TBC levels, circulation and mixing in the course of plant operations, sampling (of TBC levels and polymer concentration), temperature monitoring, insulation and refrigeration of Styrene. These methods are standard industry practice for safe storage of Styrene and the Answering Respondent has been able to run its operations without any accidents or incidents with these protocols in place.

II. FACTS LEADING UP TO THE INCIDENT

On 22.03.2020, as a part of the usual manufacturing activities and operation of the plant, an inventory of approximately one-week supply of Styrene (2,487 metric tons) was available in the onsite Storage Tanks and an additional two and half weeks supply (7,125 metric tons) was available at the Shore Tanks. Further, about 6,242 metric tons of

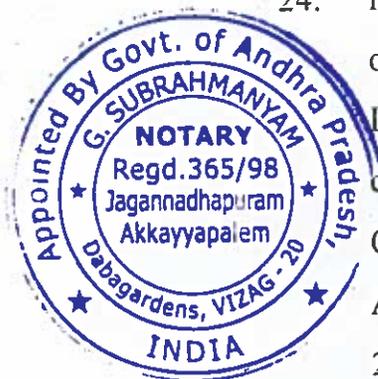


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Styrene was already en-route from South Korea to be delivered four weeks later.

22. On or around 22-24 March, 2020, following the outbreak of COVID-19, the Central Government and the Government of Andhra Pradesh started imposing various restrictions on the operations of manufacturing units like that of the Answering Respondent through various notifications under the Disaster Management Act 2005, the Epidemic Diseases Act, 1897 and the Code of Criminal Procedure 1973. On 24.03.2020, the National Executive Committee of the National Disaster Management Authority (“NDMA”) and the Ministry of Home Affairs issued guidelines imposing a complete lockdown throughout the country initially for a period of 21 days (“Lockdown”). A copy of the relevant notifications issued by the Central Government and the Government of Andhra Pradesh imposing various restrictions in view of the COVID-19 outbreak are annexed herewith as **Annexure I**.
23. In terms of the notifications issued by the Central Government and the Government of Andhra Pradesh, while industrial establishments were to remain closed, all manufacturing and production units, which required continuous process, were exempted and they were allowed to function even during the Lockdown period after obtaining permission from the District Collector.
24. In view of the risks associated with stagnation of Styrene and the nature of the industry, the Answering Respondent made a request to the District Collector to operate the Plant. This request was squarely covered by the exemption provided in the notifications issued by the Central Government and the Government of Andhra Pradesh. Accordingly, the Answering Respondent submitted a letter dated 23.03.2020 to the District Collector, Visakhapatnam (“District Collector”) apprising him about the manufacturing activities of the



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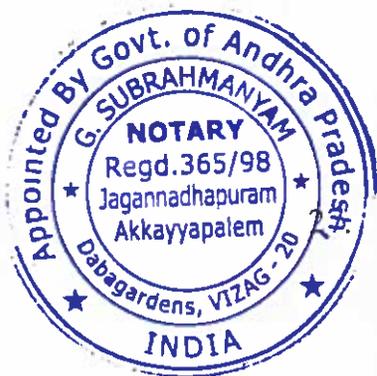
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Answering Respondent, the nature of the industry and the need for continuous operation of the Plant. Essentially, the Appellant requested the District Collector to permit the Answering Respondent to continuously operate the Plant with skeletal staff, given the nature of the industry and the risks associated with auto-polymerization and explosion in view of the stagnation of the Styrene. A copy of the letter dated 23.03.2020 addressed by the Answering Respondent to the District Collector is annexed herewith as **Annexure J**. The employees of the Answering Respondent also met the District Collector, however, the Answering Respondent was not granted the permission to operate its Plant by the District Collector.

25. As the Answering Respondent was not granted the exemption / permission to operate its Plant by the District Collector, the Answering Respondent sent another letter dated 28.03.2020 requesting sixty emergency duty permission passes to deploy skeletal staff at the Plant on 24/7 basis to for maintenance and safety measures in view of the hazardous materials stored onsite. A copy of the letter dated 28.03.2020 addressed by the Answering Respondent to the Joint Collector is annexed herewith as **Annexure K**.

26. In response to the above request, the Answering Respondent was granted forty-five passes to maintain and monitor the facility (polystyrene production was not permitted). Thus, the Answering Respondent could only deploy 15 employees per shift (24x7 basis) to enter the Plant and monitor the facility as against 50 per shift during regular operations.

In view of the limited number of employees available onsite per each shift, the Answering Respondent prepared an operating procedure for safety and maintenance at the Plant. This protocol included operating the refrigeration system, continuously monitoring temperature, and



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regularly measuring Styrene polymer concentrations and Styrene inhibitor levels in each tank.

28. On or around 20.04.2020, the Answering Respondent again reached out to the authorities to seek permission to operate the Plant with skeletal staff and an employee of the Answering Respondent attended a meeting with the District Collector. During that meeting, it was made clear to the Answering Respondent that the Answering Respondent's request for operating the Plant would not be granted as the Answering Respondent's production activities were not deemed as an essential service and that the District Collector would not provide special permissions for non-essential services.
29. On 21.04.2020, the Answering Respondent received a shipment of 6,242 MT of Styrene at the port as it could not refuse the shipment, which had set sail prior to the Lockdown. This inventory was stored at the Shore Tanks.
30. In the meanwhile, given that large quantities of Styrene was stored in the Shore Tanks, which were neither insulated or refrigerated, the Answering Respondent took steps to add TBC in the Shore Tanks (from the stock available at the Plant) on two occasions in April, 2020. The TBC was added as a precautionary measure especially because the Shore Tanks are neither insulated nor refrigerated. With this, the Answering Respondent finished its stock of TBC (48 Kg) which was available at the Plant. Nevertheless, the Answering Respondent placed two orders of 50 Kg each of TBC on 16.04.2020 and 20.04.2020 to replenish its stocks, but receipt did not materialize due to restrictions imposed by the Lockdown as the supplier was located outside Visakhapatnam. A copy of the purchase orders dated 16.04.2020 and 20.04.2020 are enclosed herewith and marked as **Annexure L**.



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31. As it was unlikely that it could undertake normal operations, the Answering Respondent continued to implement its operating procedure and continuously monitored all parameters.
32. Starting from 25.04.2020 till 02.05.2020, the Answering Respondent noticed elevated polymer concentrations at the top and bottom of the Tank M6. However, such sudden increases had previously been observed and were not reflective of any safety concerns. In any event, the inhibitor level and temperature of Styrene remained in the desired range during the entire Lockdown period (including between 25.04.2020 and 2.05.2020) thereby allaying any safety concerns or indication of any auto-polymerization. In fact, by 05.05.2020, the Tank M6 polymer concentration had stabilized and started decreasing.
33. Vide the directions issued by the Central Government and the Government of Andhra Pradesh on 01.05.2020 and 03.05.2020, factories were allowed to resume operations after taking necessary COVID-19 precautions. A copy of the directions issued by the Central Government and the Government of Andhra Pradesh on 01.05.2020 and 03.05.2020 are annexed herewith as **Annexure M**. In view of these directions, the Answering Respondent addressed an email to the District Collector undertaking to take all necessary precautions in view of COVID-19 prior to resumption of manufacturing activities. The Answering Respondent was preparing to resume manufacturing activities from 07.05.2020. However, for the sake of clarity, the Answering Respondent submits that it had not taken any concrete steps towards re-starting the manufacturing processes prior to the Incident.



III. RESPONSE OF THE ANSWERING RESPONDENT TO THE INCIDENT AND EVENTS POST INCIDENT

34. On the morning of 07.05.2020, the vapour release was first detected on CCTV at 2:57 am IST. Thereafter, the gas detector alarm, connected to

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the central system (DCS), was activated at around 2:58 am IST, alerting the concerned person in the control room. Immediately, the employees of Answering Respondent coordinated amongst themselves via walky talky devices, and attempted to access the tank farm area to understand the nature and extent of the release. The employees soon realized that the origin of the vapour was the M6 tank. Once they observed that a vapour cloud had engulfed the entire tank farm area, and was spreading rapidly, they forthwith informed the senior personnel of the Answering Respondent, while simultaneously alerting the outside agencies, such as the police and fire emergency services. On being apprised of the Incident, the Answering Respondent's senior employees started reaching the premises from 3:30 am IST onwards.

35. Initially, the vapour cloud prevented unassisted entry beyond the main gate of the premises. Nevertheless, facing that imminent risk, the Answering Respondent's employees put on Self Contained Breathing Apparatus sets and risked their lives to travel to the tank farm area and activate the sprinkler system. This succeeded in lowering the local vapour levels around M6 tank, which enabled the Answering Respondent's employees to access the tank.

36. Once the tank became accessible, the team next proceeded to undertake mitigation activities such as initiating the refrigeration system and adding high temperature inhibitors and water to the tank to control the reaction. Throughout the day, approximately 2,348 kg of inhibitor and retarder chemicals were added. In the meanwhile, about 95 MT of styrene was also transferred from M6 Tank to a nearby spare tank. The mitigation activities continued till 09.05.2020.

37. It is very important to consider that the actions taken by the Answering Respondent were complicated by the unprecedented and unanticipated nature of the event and the rapid progression of the vapor cloud during the first few minutes of the event. Further, up until the detection of the



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release, there were absolutely no indicators, which could have alerted the Answering Respondent to any potential adverse reaction that may have been happening inside the tank. As indicated previously, till 07.05.2020, the two safety related indicators (as widely accepted in the industry), being temperature and TBC levels were well within the desired limits. In fact, the temperature right until around 3:00 AM IST on 07.05.2020 was around 17 degree Celsius. This only goes to show the suddenness of the whole situation, which made it even more difficult for the Answering Respondent's employees to swiftly carry out the mitigation activities.

38. Nevertheless, the primary goal for the Answering Respondent's employees, during this period, was to prevent a fire and / or explosion, which was known to be a likely outcome in relation to incidents associated with Styrene. Undoubtedly, if the tank had exploded at that time, the consequences would have been far worse and disastrous. This is an admitted fact by the NGT Committee at Page 15 of Report 2. However, due to the prompt efforts of the Answering Respondent's employees, a fire and / or explosion was indeed avoided. This certainly would not have been possible without the correct and timely steps taken by the Answering Respondent's employees in this regard. In fact, a few employees onsite fighting the emergency were exposed to Styrene vapours and had suffered some minor short term effects such as nausea, dizziness and vomiting. The Answering Respondent prepared a brief sequence of events which took place at the plant on 07.05.2020 post the detection of the vapour release, which is enclosed herewith **Annexure N**.

In the meanwhile, on 07.05.2020, the Hon'ble High Court of Andhra Pradesh at Amaravati by an Order dated 07.05.2020 in WP(PIL) 112 of 2020, took suo moto cognizance of the Incident (basis a report (basis a report furnished by the Andhra Pradesh State Legal Services Authority) and directed the constitution of a committee of appropriate officers to



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investigate the Incident (“High Powered Committee”). A copy of the Order dated 07.05.2020 passed by the Hon’ble High Court of Andhra Pradesh in WP(PIL) Nos. 112 is enclosed herewith as **Annexure O**.

40. Pursuant to the reporting of the above Incident in the media, this Hon’ble Tribunal vide Order dated 08.05.2020 took suo moto cognizance of such reports, whereby a six-member committee was constituted for conducting a fact finding inquiry in relation to the Incident, (“NGT Committee”). Subsequently, the NGT Committee submitted its two reports to this Hon’ble Tribunal, dated 17.05.2020 and 28.05.2020, which are being assailed by way of the present Reply.
41. Separately, vide an Order dated 22.05.2020 in WP(PIL) Nos. 112, 117 and 119 of 2020, the Hon’ble High Court of Andhra Pradesh completely sealed the Answering Respondent’s premises indefinitely with entry restrictions. Subsequently, on appeal, the Hon’ble Supreme Court, in SLP (Civil)(D) No. 11636 of 2020 vide Order dated 26.05.2020, allowed the Answering Respondent to deploy only 30 specific persons at the plant only to monitor the equipment and material kept at the plant, to ensure safety. Further, vide an order dated 08.10.2020, the Hon’ble High Court of Andhra Pradesh permitted about 13 employees and 3 tax auditors of the Answering Respondent to access the finance and accounts block inside the premises for the purposes of completion of statutory audits/ corporate compliances. Therefore, till date, the Answering Respondent has no ability to completely access its official records at the Plant. A copy of the Order dated 22.05.2020 passed by the Hon’ble High Court of Andhra Pradesh in WP(PIL) Nos. 112, 117 and 119 of 2020 is enclosed herewith as **Annexure P**. A copy of the Order dated 26.05.2020 passed by the Hon’ble Supreme Court in SLP (Civil)(D) No. 11636 of 2020 is enclosed herewith as **Annexure Q**. A copy of the Order dated 08.10.2020 passed by the High Court of Andhra Pradesh in WP(PIL) Nos. 112, 117 and 119 of 2020 is enclosed herewith as **Annexure R**.



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42. In addition to the above, several other agencies / committees have also been investigating into various aspects of the Incident:
- i. High Powered Committee appointed by the State of Andhra Pradesh;
 - ii. Committees constituted by Group of Ministers, Chief Secretary, Andhra Pradesh and District Collector and Magistrate, Visakhapatnam:
 - a. Committee to inspect the plant and to verify whether LGPI has been following procedures for controlling emissions;
 - b. Committee of professors to study the scenario and advise district administration;
 - c. Committee for checking leakages;
 - d. Committee for testing of food grains, millets and pulses in vicinity of the affected areas;
 - e. Committee to ensure free treatment in the hospitals;
 - f. Committee of expert group of ten doctors to offer opinion and give inputs on follow up of patients admitted to hospitals and asymptomatic persons in the affected areas;
 - iii. Director of Factories, State of Andhra Pradesh;
 - iv. Andhra Pradesh Pollution Control Board;
 - v. Petroleum and Explosives Safety Organisation;
 - vi. State Police, Andhra Pradesh;
 - vii. A team from the Chemical, Biological, Radiological and Nuclear unit ("CBRN") of the National Disaster Response Force and an expert team of National Environmental Engineering Research Institute ("NEERI");
 - viii. National Human Rights Commission.



A copy of the action taken report dated 19.05.2020 filed by the State of Andhra Pradesh before the High Court of Andhra Pradesh in WP(PIL) No. 112 of 2020 is annexed herewith as **Annexure S**.

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43. The Answering Respondent submits that the commencement of all the above investigations in parallel, despite its best efforts, severely affected its ability to fully cooperate and assist the agencies / committees. This is more so as the Answering Respondent did not have access to its Plant/ records, with the Plant being sealed by the Hon'ble High Court of Andhra Pradesh. Therefore, the Answering Respondent craves leave of this Hon'ble Tribunal to amend / supplement the present Reply, if required, once it gets complete access to the Plant / official records.
44. In addition to the above, it is also pertinent to note that being a responsible corporate citizen, the management and the employees of the Answering Respondent have been actively involved in the following rescue, relief and rehabilitation activities in the areas surrounding the Plant:
- A task force of about eight people was formed to assist in remedial and rehabilitation activities in nearby villages with a view to provide support to the residents;
 - The Answering Respondent provided food for residents of nearby villages and illustratively, about 172,000 meals were provided during 12.05.2020 to 22.05.2020;
 - The Answering Respondent had been providing medical support to the residents of nearby villages since 11.05.2020 and as on 22.05.2020, ventilators were supplied to about 323 households with a view to mitigate the potential odour;
 - The Answering Respondent had already undertaken upon itself the medical expenses of all families, which have purportedly been affected by the Incident. Further, the Answering Respondent had also tied up with prominent hospital, Suraksha Health Park Hospital, to provide the necessary assistance to such people.
 - The Answering Respondent has also operated a 24-hour hot-line since 13.05.2020 to provide support to the residents and to take



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remedial actions. As of 22.05.2020, the hot-line services were utilized in about 116 cases.

- f. The Answering Respondent also supplied relief packages comprising of daily necessities, feminine products, cosmetic products, face masks, gloves, and food (such as rice, beans, and cooking oil) for distribution in the surrounding areas and hospitals.
- g. However, owing to the seizure of the premises by the Hon'ble High Court of Andhra Pradesh, various rescue, rehabilitation and relief equipment and food material has been lying inside the premises since 22.05.2020 and the Answering Respondent has not been able to access the same for the purposes of distribution.

IV. PRELIMINARY OBJECTIONS TO THE OBSERVATIONS/ FINDINGS IN REPORT 1 AND REPORT 2

45. Before providing its responses to the key observations/ findings in Report 1 and Report 2 on the purported causes of the Incident, the Answering Respondent seeks to place the following preliminary objections to Report 1 and Report 2 on record:

- a. At the outset, it may be pertinent to note that several observations/ findings in Report 1 and Report 2, including on purported causes of the Incident, are incorrect, incomplete, uncorroborated, premature or require further corroboration/ explanation and the Answering Respondent denies the purported causes of the Incident identified in Report 1 and Report 2. As such, there is no conclusive analysis on the cause(s) of the Incident and the observations/ findings recorded in Report 1 & Report 2, which is manifestly apparent from the use of the terms such as 'appears to' and 'possibly' while setting out the purported causes of the Incident.
- b. The NGT Committee completely failed to appreciate that the protocols in use at the plant of the Answering Respondent had



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worked successfully without any incident for many years and any purported inadequacy or shortcoming in the designs or protocols of the Answering Respondent would not have caused the Incident under normal operating circumstances. The cause of the Incident is not any purported inadequacy or shortcoming or failure of any design or protocol of the Answering Respondent, rather the Incident is attributable to the accumulated COVID-19 lockdown-driven limitations/ restrictions and the denial of permission to run the plant on a continuous basis during the Lockdown. Admittedly, the NGT Committee had indicated at paragraph 12(e) of Report 1 that owing to the Lockdown restrictions there was no circulation of Styrene since 23.03.2020. However, the NGT Committee completely ignored and failed to consider that the consequence of no circulation of Styrene since 23.03.2020, i.e. the vapour release, was caused owing to the stagnation of Styrene in view of the Lockdown restrictions.

- c. Experts, who reviewed the material which was considered by the NGT Committee and other relevant records maintained by the Answering Respondent, have been able to establish to a reasonable degree of scientific certainty that without the accumulated COVID-19 lockdown-driven limitations/ restrictions, the Incident would not have occurred under normal operating circumstances. Further, had the Answering Respondent's plant been permitted to operate during the Lockdown period, like other continuous process industries (including M/s Supreme Petrochem, a competitor of the Answering Respondent), the Incident would not have occurred. As indicated above, the Answering Respondent specifically addressed correspondence to the District Collector on 23.03.2020 seeking permission to continuously operate the plant with skeletal staff during the Lockdown in view of the nature of the industry and the risks associated with the complete shutdown of the plant and/or stagnation of the Styrene. However, no



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permission was granted by the District Collector. The NGT Committee completely failed to appreciate that the Incident would not have occurred under normal operating circumstances or if the Plant was allowed to operate during the Lockdown.

- d. Further, in 90 years of commercial production and use, there have been no reports or documented cases of human fatalities resulting from inhalation of Styrene vapours. The Answering Respondent is given to understand that Styrene is short-lived in the environment and it does not cause chronic or delayed health effects as a result of short-term, acute exposures. It does not significantly bio-accumulate in people, wildlife, biota, or plants as a result of short-term, acute exposures and many of the reported effects do not cause damage and are temporary (nausea, eye irritation, rash, dizziness, drowsiness). Therefore, based on the scientific analysis conducted by various international organizations and expert advice received, there are no recorded human fatalities due to short-term/acute exposure to Styrene vapour, like in the present case. It may also be relevant to note that the employees of the Answering Responding who were on site during the Incident, experienced short-term effects such as skin and eye irritation, which is consistent with the expected health effects of styrene. The levels of Styrene would most likely have been highest within the Answering Respondent's plant and near Tank M6. None of the employees of the Answering Respondent who were onsite reported any serious effects nor were there were any fatalities. Without examining any of these scientific observations or literature, the NGT Committee presumed that the purported deaths and other injuries or damage caused to the humans, animals and/or environment were caused by the Incident. The Report 1 and Report 2 are completely silent on examination of the causation, and the NGT Committee had not even reviewed the medical records/ autopsy reports of the persons purportedly injured owing to the Incident before



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recording an observation that death or injuries to persons was caused owing to the Incident.

- e. It is submitted that this Incident was an unprecedented one, and an in-depth understanding and analysis of the processes at the plant and the functioning of Tank M 6 was required before arriving at conclusions on the causes of the Incident. It is quite surprising that the NGT Committee managed to prepare an interim report on the root causes of the Incident, after a mere two days of inspection and not seeking any documents or information from the Answering Respondent other than on site interactions with some employees. Such analysis on the processes or protocols in use at the Answering Respondent's plant, the functioning of M6 Tank and the adequacy of the protocols/ procedures is conspicuously absent in Report 1 and Report 2. The incorrect observations and findings (factual as also scientific as indicated hereinafter below) and the unfounded/ unsubstantiated conclusions in Report 1 and Report 2 unmistakably indicate that the reports were prepared hastily without proper and thorough investigation. Therefore, this Hon'ble Tribunal ought not to rely on the observations/ findings in Report 1 and Report 2.
- f. In Report 1, it is indicated that 3 members of the NGT Committee "*observed the factory premises and affected villages on 11.05.2020 and 12.05.2020 and sent a report dated 14.05.2020*" (emphasis supplied). The Answering Respondent has not been provided a copy of any such report dated 14.05.2020. Failure to furnish all such material/ report to the Answering Respondent is in breach of principles of natural justice. The Answering Respondent ought to have been provided with a copy of all the material or reports that was relied upon by the NGT Committee on the basis of which it formed its observations/ findings and in the absence of all such material/ reports, the Answering Respondent will not be able to adequately respond to all the observations/ findings recorded in Report 1 and Report 2.



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Moreover, absent analysis of information concerning the processes followed at the Plant, Report 1 and Report 2 are superficial at best and cannot be relied on for any purpose leave alone a decision on the liability of the Answering Respondent.

V. RESPONSES TO OBSERVATIONS/ FINDINGS ON THE CAUSES OF THE INCIDENT IN REPORT 1 AND REPORT 2

46. At the outset, the Answering Respondent denies the observations at paragraph 20 of Report 1 and paragraph 6(b) of Report 2, i.e. the observations/ findings of the NGT Committee on the purported causes of the Incident, as being erroneous, misleading, speculative and inaccurate as per the records maintained by the Answering Respondent. The Answering Respondent seeks to refer to and rely on the observations in the opinions provided by the experts Dr. Michael Stern, Dr. Harri Kytömaa and Dr. Rahul Nabar which are annexed as Annexure C and Annexure D to this Reply.
47. The Answering Respondent seeks to draw the attention of this Hon'ble Tribunal to the following points, which emanate from a read of the expert opinions and are being summarized here for convenience:

- a. The Lockdown prevented normal operations at the Plant, which led to unprecedented stagnation of Styrene in the Storage Tanks and consequently increased the susceptibility of the stored Styrene to auto polymerization. The vapor release originated from Tank M6 due to a sudden exothermic auto-polymerization and resulting boiling of the Styrene within tank M6 on account of the unprecedented stagnation of the Styrene in view of the Lockdown restrictions. It is pertinent to note that the vapour release had not occurred during normal operations of the Plant and it had occurred 45 days after the Lockdown restrictions were imposed.



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- b. During normal operating conditions as also during the Lockdown period, the Answering Respondent maintained adequate protocols/ procedures that included continuous temperature monitoring, inhibitor concentration monitoring, and daily operation of the refrigeration system to contain the risk of auto-polymerization, which are standard industry practices for storage of Styrene. In fact, with these procedures, the temperature of Tank M6 and the inhibitor levels showed no deviations or signs of auto-polymerization throughout the Lockdown period until 07.05.2020. Further, given that the temperature, inhibitor levels and the polymer content remained at the desired levels, there was no signal/ warning or apprehension of any uncontrolled auto-polymerization, tank rupture, or explosion throughout the Lockdown period.
- c. In view of the above, the observations in Report 1 and Report 2 that the root cause "*appears to be lack of experience of LG Polymers India...in monitoring and maintaining full tanks of styrene that were idled for a long period of several week without operation*" are completely unfounded and without any merit.

48. As regards the observations on the design and the operation of Tank M6 at paragraph 20 of Report 1 and paragraph 6(b) of Report 2, the Answering Respondent humbly submits that these observations are erroneous and misleading. The following points may be noted in this regard, which emanate from a read of the expert opinions and are being summarized here for convenience:

- a. Firstly, the observations that the vapor release was purportedly caused as "*...the tank has no provision of monitoring storage temperature at top layers of the storage*" [refer para 20(3) of Report 1] and that "*...leaked tank was old and does not have temperature sensors at middle and top surfaces of the tank except only provision to measure the temperature at the bottom of the*



tank where refrigeration is provided....” [refer para 6(b) of Report 2] are denied as being erroneous, misleading and completely unsubstantiated as the NGT Committee, inter alia, completely fails to consider whether the existing protocols of Answering Respondent were sufficient and whether the tank design was appropriate for its intended use as a running tank. As no inquiries were made of the Answering Respondent on this issue by the NGT Committee the conclusion drawn is at best presumptuous.

- b. The Answering Respondent followed a protocol in terms of which Tank M6 had one location where the liquid Styrene temperature was continuously monitored and recorded every minute (1440 times per day) and a second location where it was checked one or more times per day. The continuous monitoring of temperature in Tank M6 was done at a measurement of 1.1 meters above the base of the tank and the daily measurements were made on the recirculation loop that draws Styrene from 0.3 meters from the base.
- c. The NGT Committee also fails to provide any analysis or justification to demonstrate that monitoring of temperature at additional locations would have provided sufficient warning of the Styrene vapour release.
- d. Further, the observation that Tank M6 does not have “...*the provision for monitoring temperatures at vapour space...*” [refer para 12(e) of Report 1] is without any merit as the Answering Respondent’s existing protocols for temperature measurement were sufficient during normal operating conditions and in any event, the vapour release event was sudden and daily vapor space temperature measurement would not have detected, prevented or mitigated the vapour release.



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- e. Furthermore, the observation that the vapour release happened as “...*there is no monitoring system for dissolved oxygen in the vapour space which might have fall down below 6%*” [at para 20 (2) of Report 1] is denied as being erroneous as the headspace in the Tank M6 is occupied by air and air has an oxygen concentration of 20.9% by volume. Therefore, there was no requirement for measuring oxygen concentration in the headspace as the concentration of oxygen in ambient air far exceeds the requirement and in any event, there is no evidence to suggest that a deficiency of oxygen caused or contributed to the vapour release or that such measurement, even if unnecessary for the reasons indicated above, would have provided any information that would have prevented or mitigated the vapour release.
- f. Moreover, the observations of the NGT Committee that the vapour release happened as “...*refrigeration system is not being operated for 24 hours*” [at para 20 (4) of Report 1] is denied as being erroneous and without any merit as the NGT Committee failed to appreciate that throughout the Lockdown period, the refrigeration system was operated appropriately and effectively and the fact that the temperatures in the tanks were recorded at the desired levels during the Lockdown indicated that the refrigeration system was operating as intended. As such, the NGT Committee does not provide any analysis or justification to demonstrate that operation of refrigeration system for additional time would have prevented the Styrene vapor release.
- g. The observation that “...*there is no external water spray arrangement over the storage tank for exceeding ambient air temperature and also any unmanned hose arrangement..*” [refer para 6(b) of Report 2] is denied as being completely inaccurate



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and incorrect and in fact, the sprinklers were opened by the Answering Respondent's employees onsite at the time of the Incident.

49. Further, the observation of the NGT Committee that "...the unit failed to assess this situation due lack in handling experience by trained manpower. The root cause thus appears to be lack of experience of LG Polymers India..." [refer Page 16 of Report 2 & Para 20 (5) of Report 1] are denied as being completely erroneous, inaccurate and without any merit. Furthermore, the observation that "...human failure and negligence of the persons in-charge of the plant and the maintenance personnel of the storage tanks..." [refer para 20(5) of Report 1] caused the vapour release is erroneous, misleading and contrary to the records. The Answering Respondent seeks to refer to and rely upon the opinions of the experts Dr. Michael Stern, Dr. Harri Kytömaa and Dr. Rahul Nabar which are annexed as Annexure C and Annexure D and draw the attention of this Tribunal to the following points which emanate from a read of the expert opinions and are being summarized here for convenience:

- a. As indicated above, the Incident was a result of the abrupt and sudden imposition of the Lockdown which led to the stagnation of Styrene in Tank M6 for an unusually prolonged period of time. Immediately, after the declaration of the Lockdown, the Answering Respondent, in fact, had requested the government authorities to allow it to continue operations given the risks of Styrene stagnation, however, such requests were repeatedly denied by the authorities.
- b. The plant/ the Storage Tanks were never designed / intended to be used for storing Styrene for such prolonged periods and the NGT Committee completely failed to take into consideration this



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fact while attributing lack of responsibility on the Answering Respondent's personnel.

c. Nevertheless, the Answering Respondent, faced with this unprecedented situation, deployed appropriate and reasonable measures to continuously monitor the contents of all the Storage Tanks, both from a quality and safety standpoint, throughout the Lockdown period. The chiller / refrigeration system was activated on a daily basis for an appropriate duration, and the temperature of the tank was monitored on a 24& 7 basis through the DCS system. Further, on a regular basis, samples were tested from the Storage Tanks to check the status of the parameters of Styrene. The available data on record suggests that the widely accepted safety indicators of Styrene (being TBC quantity and temperature) were well within the desired range throughout the lockdown period, right up till around 3 AM on 07.05.2020 (when the release was first detected). Thus, the Answering Respondent, despite taking best measures, did not receive any indications of a possible adverse reaction taking place inside the tank, prior to the release. Hence, it is entirely incorrect to state that "*the root cause thus appears to be the lack of experience*" of the Answering Respondent's personnel in monitoring and maintaining the Storage Tanks. The NGT Committee also failed to appreciate that the plant was being run by the Answering Respondent for more than two decades in a seamless fashion.

d. Further, the NGT Committee wrongly concludes that prima facie, the vapour release happened due to "*...Insufficient TBC concentration in styrene due to unavailability of TBC in the plant....*" [refer para 20(1) of Report 1] and that "*...no TBC was topped up in the affected tank M6 since April 1 since there was no stock at site*" [refer page 16 of Report 2]. Firstly, the Answering Respondent's protocol included regular monitoring



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of the TBC content and the TBC parameters were within the prescribed threshold requirements. Further, the NGT Committee completely failed to appreciate that with a view to mitigate the risk of auto-polymerization in the Styrene stored at the Shore Tanks (which lacked insulation and refrigeration facilities), the Answering respondent had added approximately 20 kg out of its approximately 45 kg stock of TBC to Shore Tanks on 01.04.2020 (10 kg per tank). As such, out of abundant caution, the Answering Respondent had placed an order for more TBC on 16.04.2020 and on 20.04.2020, however, in view of the Lockdown restrictions, it was unable to obtain. Post the delivery of Styrene subsequently on 21.04.2020, the Answering Respondent added remaining TBC supply to the Shore Tanks. In any event, the purported unavailability of TBC had no correlation to the TBC concentration in Tank M6 as there were no indications that additional TBC was warranted throughout the Lockdown period.

- e. The Answering Respondent had also monitored the polymer levels in Tank M6. While polymer levels had initially found to be increasing in the last week of April 2020, by 05.05.2020, it was observed that the polymers levels had decreased. The Answering Respondent submits that polymer levels did not raise any concerns as the levels were still within an acceptable limit and in any event, the elevated levels of polymer concentration was not abnormal or unusual for the Answering Respondent. In view of this, the observation of the NGT Committee that rise in polymer levels was "*possibly*" a starting point of the problem [refer Page 15 of Report 2] is merely speculative and has no basis / justification.

- f. Separately, the observations of the NGT Committee at paragraph 15 of Report 1 are completely misconstrued insofar as the



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addition of TBC and the alleged failure of the Answering Respondent's employees to make efforts to subside the intensity of the vapours. At the outset, it is clarified that the Answering Respondent never intended to add TBC to Tank M6 after the detection of the vapour release. This was not because that the stocks were non-existent, but because TBC is an ineffective inhibitor when the Styrene is at high temperature. The Answering Respondent used other inhibitors, which were effective at high temperatures, which were ultimately successful in mitigating the vapour release. Insofar as the observation on failure to make any efforts to subside the vapours is concerned, as indicated above, immediately following detection of the vapour release, the GPPS DCS Control Room operator announced over walkie-talkie, which was heard by the Night Duty Officer who arrived on the spot quickly. Initially, a vapour cloud prevented unassisted entry beyond the main gate, nevertheless, facing that imminent risk, the employees of the Answering Respondent put on Self Contained Breathing Apparatus sets and risked their lives to activate the sprinkler system, which succeeded in lowering local vapour levels enough to allow the employees to access the Tank M6. Once the tank became accessible, the team proceeded with containment and mitigating actions including addition of inhibitors, transfer of about 95 MT of Styrene into a spare tank and addition of water into the tank. Due to such efforts, fire and / or explosion were indeed avoided, thereby mitigating the damage to a large extent. Furthermore, observations in the Report 1 that the employees of the Answering Respondent ran away from the site and no efforts were made to mitigate the intensity of the vapours runs contrary to the observations in Report 2, which explicitly records the employees of Answering Respondent were onsite during the Incident and were undertaking response measures.



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50. Therefore, in view of the above and in view of the opinions of the experts annexed at Annexure C and D, the Answering Respondent submits that the observations/ findings in Report 1 and Report 2 on purported causes of the Incident are denied as being erroneous, speculative, misleading and unsubstantiated and this Hon'ble Tribunal ought not to rely on any such observations/ findings.

VI. RESPONSES TO OBSERVATIONS/ FINDINGS ON EFFECTS OF THE INCIDENT IN REPORT 1 AND REPORT 2

51. At the outset, the Answering Respondent denies the observations at paragraph 7 of Report 1 and paragraph 6(c) to 6(i) of Report 2, i.e. the observations/ findings of the NGT Committee on the purported effects of the Incident, as being unsubstantiated and without any merit. The Answering Respondent seeks to refer to and rely on the observations in the opinions of provided by the experts Dr. Paul A. Nony and Dr. Rakesh Dubey which are annexed as Annexure E and Annexure F to this Reply.
52. The Answering Respondents seeks to draw the attention of this Tribunal to the following points which emanate from a read of the expert opinions and are being summarized here for convenience:

- a. At the outset, the Answering Respondent denies that the Incident caused the loss of lives of 12 persons and injuries to about 585 people or caused damage to the environment/ animals in view of the preliminary submissions indicated above and the same are not being repeated herein for the sake of brevity.
- b. Report 1 and Report 2 are completely silent on examination of the causation, and the NGT Committee had not even reviewed the medical records/ autopsy reports of the persons purportedly injured owing to the Incident before recording an observation



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that death or injuries to persons were caused owing to the Incident.

- c. The NGT Committee wrongly observed that “...*had any workman present at the affected tanks, he should have been the victim of vapour gas and he should have been shifted to the hospital for treatment...*” [refer para 15 of Report 1] without taking into account that the employees of the Answering Respondent, who were on site at the time of Incident taking mitigating steps, only experienced short-term effects such as skin and eye irritation and none of them reported any serious effects nor were there were any fatalities.
- d. The NGT Committee presumed that the purported deaths and other injuries or damage caused to the humans, animals and/or environment were caused by the Incident without any analysis/ substantiation.
- e. Further, the observation of the NGT Committee at paragraph 6(g)(3) of Report 2 are denied as being erroneous and misleading. It may be pertinent to note that Styrene is not a known human carcinogen. There is no scientific connection between short-term, acute exposures to styrene and an increased risk of any type of cancer.
- f. Furthermore, the observations/ findings in Report 1 and Report 2 on extent of damage done to the environment are denied as being erroneous, inaccurate and unsubstantiated and the Answering Respondent seeks to refer to and rely upon the opinion of the experts as indicated above.

Firstly, it may be pertinent to note that admittedly, concentrations of Styrene could not be measured until many hours after the Incident. Therefore the assertion that “..*the concentrations of*



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styrene were high at the time of the accident in the villages..” [refer para 6(c) of Report 2] is completely speculative and misleading. Further, the Answering Respondent is given to understand that the air, water, and soil sampling done by CSIR-NEERI and CBRN was erroneous and it appears no control samples were collected to do a ‘before-after’ analysis of the samples. In any event, even as per the air, water, and soil sampling conducted by the team of CSIR-NEERI and CBRN in the surrounding areas in the days following the Incident, the levels of Styrene were evidently low or were primarily below the detection limit. As such, as per the samples collected and field examinations done by the experts, the Answering Respondent is given to understand that the Styrene vapour decomposed post the Incident without bio accumulating and therefore, long-term environmental and health testing is neither a concern nor necessary. Therefore, the recommendations at paragraph 6(i) of Report 2 are unwarranted as no traces of Styrene have been found in groundwater, soil, air or surface water samples specially since 17.05.2020 and as such no further studies are required.

53. Therefore, in view of the above and in view of the opinions of the experts annexed at Annexure E and F, the Answering Respondent submits that the observations/ findings in Report 1 and Report 2 on purported effects of the Incident are completely baseless and unsubstantiated and this Hon’ble Tribunal ought not to rely on any such observation/ finding.



VII. RESPONSES TO OBSERVATIONS/ FINDINGS ON THE ENVIRONMENT CLEARANCE IN REPORT 1 AND REPORT 2

54. The Report 1 and Report 2 allege that the Answering Respondent was operating the plant without the required Environmental Clearance (EC) under the EIA Notification dated 14.09.2006 (“2006 EIA

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Notification"). It is most respectfully submitted that neither of the reports even mention leave alone demonstrate any link between the alleged lack of EC and the Incident.

55. The Answering Respondent has the following submissions to make in this regard:

- a. Pertinently, an Environmental Clearance Certificate dated 23.11.1990 for the plant was duly obtained by the predecessor of the Answering Respondent from the Energy, Forest, Environment, Science and Technology Department, Government of Andhra Pradesh. Neither of the reports, however, even refer to the said certificate. A copy of the Environmental Clearance Certificate dated 23.11.1990 issued in favour of the predecessor of the Answering Respondent is annexed herewith as **Annexure T**.
- b. Admittedly, the EIA Notification dated 27.01.1994 ("1994 EIA Notification") did not apply to the Plant (being a pre-existing plant) or to any expansion undertaken at the Plant as none of the expansions met the threshold criteria laid down under the 1994 EIA Notification.
- c. Moreover, even post notification of the 2006 EIA Notification, the Answering Respondent was always under a bona fide belief that the activities carried on by it were not covered within the scope of 2006 EIA Notification and therefore did not require an EC. It may be noted that the APPCB had by its letter dated 07.03.2012, while considering the Answering Respondent's application for "Consent for Establishment" in relation to the manufacture of Polystyrene and Expandable Polystyrene, directed the Answering Respondent to first seek an EC from the Ministry of Environment, Forest and Climate Change.



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Government of India ("MoEF"). In response thereto, the Answering Respondent vide its letter dated 21.03.2012 to APPCB had submitted that the plant was not covered under the 2006 EIA Notification. It was inter alia stated that (i) no Styrene was manufactured at the plant; (ii) polystyrene was being manufactured by a simple conversion of Styrene into polymer by way of an exothermic reaction which could not be classified as a petrochemical manufacturing process (iii) the plant did not generate process emissions and the process effluent water was treated at the Effluent Treatment Plant. It is submitted that after this representation from the Answering Respondent, the requirement raised by the AAPCB for seeking an EC from MoEF was withdrawn. Therefore, APPCB too was of the view that the manufacturing activities, which were carried on by the Answering Respondent did not fall within the scope of the 2006 EIA Notification. A copy of the relevant extracts of the Minutes of Meeting of the CFE Committee dated 29.02.2012 is annexed herewith as **Annexure U**. A copy of the letter dated 07.03.2012 issued by the APPCB to the Answering Respondent is annexed herewith as **Annexure V**. A copy of the letter dated 21.03.2012 issued by the Answering Respondent to APPCB is annexed herewith as **Annexure W**. A copy of the relevant extracts of the Minutes of the Meeting of the CFE Committee dated 17.04.2012 is annexed herewith as **Annexure X**. A copy of the CFE dated 28.04.2012 issued by the APPCB in favour of the Answering Respondent is annexed herewith as **Annexure Y**.



- d. It is pertinent to mention that the Answering Respondent duly applied for and obtained Consents for Establishment, Consents to Operate and Hazardous Waste Authorizations, as were required under the Water (Prevention & Control of Pollution) Act, 1974, the Air (Prevention & Control of Pollution Act 1981 and the Hazardous & Other Wastes (Management and

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Transboundary Movement) Rules 2016. A tabulated list containing the details of the CFE and CFO issued to the Answering Respondent till date is enclosed herewith as **Annexure Z**. Regular inspections were carried out by the APPCB at the Plant from time to time and no deviations / non-conformity with applicable laws / rules was pointed out, which remain unaddressed.

- e. Moreover, when the Answering Respondent had proposed to set up a separate unit for the manufacture of Engineering Plastics, the APPCB while issuing the CFE dated 04.05.2017 directed the Answering Respondent to seek a clarification from the MoEF on the applicability of the 2016 EIA Notification for the manufacture of Engineering Plastics. In response, the Answering Respondent made a representation to APPCB pointing out that Engineering Plastics had been exempted from the purview of the 2006 EIA Notification by the Amendment Notification dated 25.06.2014. In view of the representation, the APPCB vide an amended CFE dated 07.08.2017 removed the condition of seeking such clarification on the applicability of the 2006 EIA Notification. A copy of the relevant extracts of the Minutes of the Meeting of the CFE Committee dated 28.04.2017 is annexed herewith as **Annexure AA**. A copy of the CFE dated 04.05.2017 issued by the APPCB in favour of the Answering Respondent is annexed herewith as **Annexure BB**. A copy of the letter dated 03.06.2017 issued by the APPCB to the Answering Respondent is annexed herewith as **Annexure CC**. A copy of the Minutes of the Meeting of the CFE Committee dated 27.07.2017 is annexed as **Annexure DD**. A copy of the Amendment to the CFE Order dated 07.08.2017 issued by the APPCB is annexed herewith as **Annexure EE**.



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f. On receiving advice regarding applicability of the 2006 EIA Notification, the Answering Respondent first approached the MoEF to seek an EC relating to an expansion of manufacturing capacity in connection with both polystyrene and expandable polystyrene on 03.01.2018. The said application was, however, withdrawn. The Answering Respondent on 12.04.2018, made an application to the State Environment Impact Assessment Authority ("SEIAA") for an EC to regularise all existing operations and capacity, as well as further expansion of capacity. This application was made in line with a notification dated 14.03.2017 issued by the MoEF. Although the Answering Respondent had not been found to be in violation of the requirement of not having obtained an EC, with a view to regularise its operations, this was the only option available to the Answering Respondent.

It is pertinent to mention that this application remained pending ever since and was not considered on merits even once.

g. The application dated 12.04.2018 was filed by the Answering Respondent before the State Environment Impact Assessment Authority ("SEIAA") as a Category 'B' project under the bona fide belief that the plant was located in a notified industrial area. (as pleaded hereinabove) The application came up for consideration by the State Expert Appraisal Committee ("SEAC") in June 2019. The SEAC in its meeting recommended the transfer of the Answering Respondent's application to the MoEF on the ground that the plant was Category 'A' project, which was required to be considered by the MoEF. The recommendations of the SEAC were accepted by State Environmental Impact Assessment Authority ("SEIAA") in its meeting held on 9th & 10th July 2019. However, a formal transfer of the application to the MoEF was made by SEIAA only



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vide a letter dated 07.01.2020 i.e. after a lapse of nearly 5 months for no fault of the Answering Respondent. A copy of the relevant extracts of the Minutes of the Meeting of the SEAC dated 20.06.2019 is annexed herewith as **Annexure FF**. A copy of the relevant extracts of the Minutes of the Meeting of the SEIAA dated 09.07.2019 is annexed herewith as **Annexure GG**. A copy of the letter dated 12.08.2019 by the SEIAA to the MoEF is annexed herewith as **Annexure HH**. A copy of the letter dated 23.10.2019 issued by the Answering Respondent to SEIAA is annexed herewith as **Annexure II**. A copy of the letter dated 27.11.2019 issued by the Answering Respondent to the SEIAA is annexed herewith as **Annexure JJ**. A copy of the letter dated 07.01.2020 from the SEIAA to the MoEF is annexed herewith as **Annexure KK**.

- h. It is pertinent to mention that the Answering Respondent's application for seeking post facto clearance has never been considered on merits. The same was taken up by the MoEF for the first time on 19.05.2020 i.e. after the date of Incident. On the said date, the EAC deferred considering the application till the completion of the ongoing judicial proceedings. A copy of the relevant extracts of the Revised Agenda issued by the EAC is annexed herewith as **Annexure LL**. A copy of the relevant extracts of the Minutes of the Meeting of the EAC dated 18.05.2020 /19.05.2020 is annexed herewith as **Annexure MM**.

As is evident, the Answering Respondent always bona fide believed that the activities carried on by it were not covered under the 2006 EIA Notification. This stand of the Answering Respondent is supported by the APPCB. In fact, APPCB had after the Incident by its letter dated 12.05.2020 sought for a clarification from the MoEF whether the manufacturing activities carried on by the Answering Respondent fell within the purview of the 2006 EIA Notification. As is evident, as has



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also been recorded in the Report 2, there was lack of clarity even at the end of APPCB with respect to the provisions of 2006 EIA Notification and its amendments.

57. Additionally, it may be mentioned that the Answering Respondent is also subject to regulation by the Petroleum & Explosives Safety Organisation (“PESO”). PESO treats Styrene to be a “Class B” petroleum (due its flash point), with a valid license required for its storage at the site premises, consistent with the Petroleum Rules, 2002. The Petroleum Rules (including any license issued thereunder) exclusively apply to the import, storage, transport, refining and usage of all types of petroleum. The Rules contain built in international standards and codes.
58. Notably, any license issued by PESO to a new petroleum installation (including any addition/alteration to a licensed installation), requires the certification of tank testing and safety, only to be issued by a competent person. The Answering Respondent possessed a valid PESO license at the time of the Incident. The Answering Respondent’s PESO license indicates that its Styrene storage underwent the aforementioned screening process. PESO undertook an inspection of the licensed premises on 08.12.2018. The inspection did not indicate any major violation related to the Petroleum Rules.
59. Therefore, it is evident that the Plant and the storage facilities for Styrene were subjected to multiple regulators who inspected the premises at frequent intervals and it is not as if the Answering Respondent was covertly operating such a large Plant without any checks or conditions on its operations.

60. In view of the above, the Answering Respondent humbly requests this Tribunal to set aside Report 1 and Report 2. Further, in terms of Section 19 of the National Green Tribunal Act, 2010 the Answering Respondent

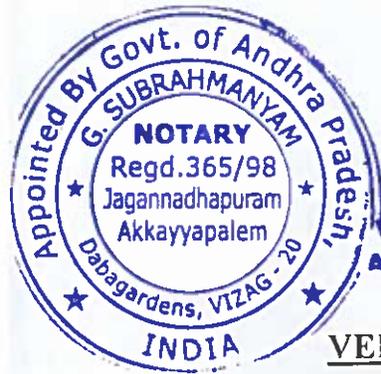
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craves leave of this Tribunal to cross-examine the members of the NGT Committee at an appropriate stage in relation to their observations/ findings in Report 1 and Report 2.

61. It is stated that the facts stated in the Affidavit are true to the best of my knowledge as per the records of the case and the submissions made therein are based on legal advice and expert advice received by me and believed to be true and correct.



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[Signature]

DEPONENT

VERIFICATION:

I, the Deponent above named, do hereby verify that the contents of foregoing affidavit are true and correct to my knowledge, no part of it is false and nothing material has been concealed therefrom.

Verified at Vishakhapatnam on this 9th day of November, 2020.

[Signature]

DEPONENT

P. Arun Kumar
 Authorised Official
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 ADVOCATE & NOTARY
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My Commission Expires
On 27-05-2024

Mr. Saurabh Mishra, AOR

Ms. Aishwarya Bhati, Sr. Adv.
Mr. Gurmeet Singh Makker, AOR
Mr. Shovan Mishra, Adv.

UPON hearing the counsel the Court made the following
O R D E R

Mr. Mukul Rohatgi, learned Senior Advocate for the appellants submits that the Report of the Committee having been uploaded on 28.05.2020 and the matter having been listed on 01.06.2020, appropriate response to the said Report could not be filed by the appellant.

In the circumstances, we give an opportunity to the appellant to file response to the Report of the Committee within 10 days from today.

Let a copy of the reply to the report be also placed on record before this Court.

Mr. Rohatgi, learned Senior Advocate further submits that the matter is posted before the NGT on 03.11.2020.

Considering the fact that this Court is now seized of the matter, we direct the NGT to defer the hearing of the matter till further orders by this Court.

List these matters alongwith SLP(C)Nos.10117-10119/2020 on 16.11.2020 at the end of the Board before the appropriate Court.

(INDU MARWAH)
COURT MASTER (SH)

(BEENA JOLLY)
COURT MASTER (NSH)

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Harri K. Kytömaa, Ph.D., P.E., CFEI, FASME

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Professional Profile

Dr. Kytömaa specializes in mechanical engineering and the analysis of thermal and flow processes. He applies his expertise to the investigation and prevention of failures in mechanical systems. He also investigates fires and explosions and their origin and cause. He consults in the utilities, oil and gas, and chemical industries. Dr. Kytömaa's project experience includes consumer products, intellectual property matters, automobiles, aircraft, turbines, compressors, boilers, steam generators, pneumatic and hydraulic systems, instrumentation, nuclear waste management, heat transfer systems, fuel distribution, delivery and storage systems, including LNG facilities.

Dr. Kytömaa has decades of experience in the area of dynamics and thermal hydraulics of piping systems, valves and pipelines. He has developed flow modeling tools for such systems and their components and has applied these to drilling and downhole applications. He pioneered the modeling of the acoustics of drilling fluid piping systems for acoustic telemetry and Measurement-While-Drilling (MWD), which was one of the enabling technologies for directional drilling. Dr. Kytömaa has also developed ultrasonic techniques for both medical and engineering applications, including instrumentation for flow measurement and the characterization of dense suspensions.

Dr. Kytömaa was Assistant Professor and Associate Professor of Mechanical Engineering at the Massachusetts Institute of Technology, where he was head of the Fluid Mechanics Laboratory. He has also held positions as Visiting Professor at the Helsinki University of Technology and at the DOE Pacific Northwest Laboratory in Washington and served as Lecturer at the Worcester Polytechnic Institute. Dr. Kytömaa consulted for Teleco Oil Field Services, Inc., developing MWD technology and other downhole applications.

Academic Credentials & Professional Honors

Ph.D., Mechanical Engineering, California Institute of Technology (Caltech), 1986

M.S., Mechanical Engineering, California Institute of Technology (Caltech), 1981

B.Sc., Engineering Science, Durham University, England, *First Class with Honors*, 1979

Fellow of the American Society of Mechanical Engineers

Keynote Speaker: AIChE 2020 Virtual Spring Meeting and 16th Global Congress on Progress Safety. Topical Conference on Gas Utilization. August 18, 2020

Session Chairman, LNG Plant Safety and Protection: 2014, 2013, 2012 and 2011 AIChE Spring Meetings & 10th, 9th, 8th and 7th Global Congress on Process Safety

Keynote Speaker: AIChE 2014 Spring National Meeting, 10th Global Congress on Process Safety. Topical Conference on Gas Utilization, New Orleans, LA, March 30-April 3, 2014

Liquefied Natural Gas (LNG) installations and equipment, ISO /TC 67/ WG10: Committee Member, 2008-2014

Outstanding Presentation Award, AIChE Spring Meeting, 2013

Excellence Award at the SAE 2006 World Congress & Exhibition

Lewis F. Moody Award for best paper on a subject useful in engineering practice presented to American Society of Mechanical Engineers (ASME), 1993

Henry L. Doherty Professor in Ocean Utilization, 1991-1993

Chairman, Organizing Committee, Engineering Foundation Workshop, Davos, Switzerland, 1993

National Science Foundation Review Panelist, Washington, DC, 1990

National Science Foundation Group Leader, Acoustic Methods Workshop on Visualization of Particulate Two-Phase Flows, Washington, DC, 1990

Diver in the Finnish Navy, rank Able Seaman, Distinguished Service, 1980

Institute of Mechanical Engineers Prize for Outstanding Project Work (United Kingdom), 1979

Licenses and Certifications

Licensed Professional Mechanical Engineer, California, #34290

Licensed Professional Mechanical Engineer, Massachusetts, #48202

Licensed Professional Mechanical Engineer, Louisiana, #PE.0035054

Licensed Professional Mechanical Engineer, Maine, #12370

Licensed Professional Mechanical Engineer, Michigan, #6201057546

Licensed Professional Mechanical Engineer, Washington, #47486

Licensed Professional Mechanical Engineer, New York, #089361

Licensed Professional Mechanical Engineer, Arkansas, #16481

Licensed Professional Mechanical Engineer, Alabama, #35697-E

Licensed Professional Mechanical Engineer, Oklahoma, #28024

Licensed Professional Mechanical Engineer, New Jersey, #24GE05391800

Licensed Professional Mechanical Engineer, Florida, #84434

Licensed Professional Mechanical Engineer, Texas, #129541

Certified Fire and Explosion Investigator (CFEI, Registration No. 13524-6843) in accordance with the National Association of Fire Investigators (NAFI) National Certification Board per NFPA 921 Section 11.6.4

Certified Fire Investigator (CFI certificate No. 20-005) in accordance with the International Association of Arson Investigators (2009-2013)

Fire Investigation 1A Certification accredited by the California State Fire Marshal

Short Course on Aircraft Fire protection/Mishap Investigation, AFP Associates, November 9, 2001

National Waste Operations and Emergency Response Training, 29 CFR 1910.120 (1994-2000)

Asbestos Worker, Certificate No. 97-164-112-102, pursuant to Title II of the Toxic Substance Control Act, 15 USC 2646, 1997

Short Course: Research state-of-the-art in two-phase flows and thermal hydraulics. Faculty: Professors R.T. Lahey Jr, D.A. Drew, O.C. Jones, M.Z. Podowski, A.E. Bergles, Rennselaer Polytechnic Institute, 1988.

Nordic Sportsdiver's Certificate, CMAS International Diving Certificate "2 stars," No 1076

Open Water Certified Scuba Diver, NAUI Certification #: kyto062958harsd

Enriched Air Diver, Nitrox, Max 40% O2 concentration, PADI Diver No. 0604055220

Professional Affiliations

American Society of Mechanical Engineers (Fellow)

American Institute of Chemical Engineers

International Association of Fire Investigators

Society of Fire Protection Engineering

Society of Petroleum Engineers

Sigma Xi, The Scientific Research Honor Society

National Fire Protection Association

Languages

Finnish

French

Patents

Hydrogen generator, US 9705145 B2 (Kmetich TJ, Zsigo GA, Mick AR, Kytömaa HK), 2017

Publications

Kytömaa HK, Boehm P, Osteraas J, et al. An integrated method for quantifying and managing extreme weather risks and liabilities for industrial infrastructure and operations. *Proc Safety Prog.* 2019; e12087. <https://doi.org/10.1002/prs.12087>

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Professional Profile

Dr. Stern is a chemical engineer in Exponent's Thermal Sciences Practice working in the areas of industrial and chemical processing, process safety, product safety, failure analysis, and incident investigation. He specializes in the areas of carbon capture and carbon abatement systems, chemical and petroleum separations, combustible dust handling and processing, consumer products with flammable liquids, electrostatic safety, reactive materials, and electrochemical systems including batteries. Specifically, Dr. Stern has investigated chemical separation systems ranging from biomedical devices to full scale industrial facilities producing a range of petroleum and chemical products. He has investigated performance issues and accidents related to carbon dioxide (CO₂), sulfur dioxide (SO₂), and hydrogen sulfide (H₂S) gas treatment systems at power plants, refineries, and chemical plants. Dr. Stern has also investigated accidents at petroleum refineries and natural gas processing facilities, designed oil/water separation equipment for the crude oil, and evaluated infringement and validity of patents for petroleum technologies. He has also performed a number of dust hazard analyses (DHA) for manufacturers handling organic and metal dusts and assisted companies cited by OSHA for combustible dust, Process Safety Management (PSM), or electrical classification violations.

Dr. Stern has performed numerous experiments and analyses to assess the feasibility of a fire or explosion scenario for consumer products, home utilities, industrial processes, power plants, refineries, and chemical plant processes. His ongoing research includes investigating the competency of ignition sources in industrial flash fires, combustible dust hazards, and mechanisms for electrical fires. Dr. Stern serves on several committees responsible for authoring standards related to flammable liquid safety with consumer products chemical hazards and electrical classification in hazardous environments.

Prior to joining Exponent, Dr. Stern was a graduate research assistant in the Department of Chemical Engineering at the Massachusetts Institute of Technology. He developed a new electrochemically-mediated technology for carbon dioxide separations from post-combustion flue gases from sources including coal-fired power plants, cement furnaces, and aluminum processing equipment.

Academic Credentials & Professional Honors

Ph.D., Chemical Engineering, Massachusetts Institute of Technology (MIT), 2014

M.S., Chemical Engineering, Massachusetts Institute of Technology (MIT), 2011

B.S., Chemical Engineering, Lehigh University, 2008

Licenses and Certifications

Licensed Chemical Engineer, California, #6730

Licensed Professional Engineer, Texas, #136150

Certified Fire and Explosion Investigator (CFEI) in accordance with the National Association of Fire Investigators National Certification Board per NFPA 921 Section 13.6.5.2

Blasting Certificate of Competency, Massachusetts, #BL-007223

Professional Affiliations

American Institute of Chemical Engineers — AIChE (Senior Member)

National Association of Fire Investigators — NAFI (Member, CFEI)

American Society for Testing and Materials — ASTM (Member of Committees E27 Hazard Potential of Chemicals and Sub-Committees 15.10 Standards for Flammable Liquid Containers and F15.72 Torch Fuels)

National Fire Protection Association — NFPA

- Alternate Member of the Committee on Electrical Equipment in Chemical Atmospheres responsible for NFPA 496 Standard for Purged and Pressurized Enclosures for Electrical Equipment, NFPA 497 Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, and NFPA 499 Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

- Alternate Member of the Committee on Fundamentals of Combustible Dusts responsible for NFPA 652 Standard on the Fundamentals of Combustible Dust

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LG Polymers India Pvt., Ltd
Styrene Handling and Response
Background and Qualifications

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Dr. Rahul Nabar, Ph.D.

Dr. Nabar graduated with a Bachelor's Degree in Chemical Engineering from the University of Mumbai (2003) and subsequently worked on doctoral research at the University of Wisconsin – Madison in the Department of Chemical & Biological Engineering. He received his Ph.D. (2009) from the University of Wisconsin – Madison studying the applications to simulation techniques for selected problems in hydrocarbon (petroleum) processing. During his Ph.D. he worked on several problems related to Catalysis sponsored by the US-Department of Energy and private sector Oil and Gas companies with a focus on Gas to Liquid conversions and catalyst-poisoning. Subsequent to his Ph.D. he completed post-doctoral research at the University of Wisconsin (2009-2010) with a combination of experimental and simulations related to petrochemical processes. He also led a project for high-performance scientific computing for Chemical Engineering applications at the University of Wisconsin.

Dr. Nabar presently resides in the City of Mumbai and works as an independent consultant in the chemical industry. His primary domains of interest include process-engineering, regulatory affairs, and process development with a focus on fine / specialty chemicals. In this context he has been working on projects that utilize styrene for chemical processes at industrial and lab scale and hence developed a professional interest in the body of knowledge regarding the safe storage and handling of styrene and also the phenomenon of auto-polymerization and strategies to prevent it.

Dr. Nabar's projects tend to be at the interface of industrial practice and academic research. He is presently also teaching as an Adjunct Associate Professor (part time) at the India Institute of Technology, Bombay where his principal academic and scientific focus is exposing students to industrial practices especially in the context of fine chemicals. He lectures on chemicals-related topics at several other educational institutions in the city of Mumbai. One of his current interests is projects that bridge the gap between academia and industry and to work on ways to enhance process safety in the Indian industry (with a focus on SMEs).

The CTEH logo is a dark blue rectangle with the letters 'CTEH' in white, bold, sans-serif font.

LG Polymers India Pvt., Ltd

Chemical Emergency Response

CTEH Background and Qualifications

CTEH, LLC

Contact: Paul Nony | pnony@cteh.com | (501) 352-3131

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ABOUT CTEH

Company Overview

CTEH is an environmental consulting firm rooted in science and dedicated to helping companies, governments, and communities prepare for, respond to, and recover from threats to their environment and people. We apply the brightest minds, state-of-the-art technology, and conclusive data to resolve complex health, safety, environmental, toxicological, and management challenges. Our more than 22 years of experience enables us to manage complex situations better than anyone else.

We are focused on acquiring top industry professionals who not only have achieved high academic goals, but who work in the real world and excel in applying technical aptitude gained through academics to environmental health challenges in diverse settings. CTEH has responded to more than 2,500 chemical emergency responses. We have firsthand experience with release issues, chemical exposures, and environmental concerns that often arise in your industry. We employ management professionals, Ph.D. toxicologists, Certified Industrial Hygienists (CIH), and environmental scientists. Each brings a wealth of institutional knowledge of subject matter ranging from developing job aides to drafting sampling analysis plans. The most profound characteristic of this team is that all professional level scientists are active in conducting field work across all disciplines including emergency response.

About Paul Nony, PhD, CIH, CSP



Dr. Paul Nony is a Principal Toxicologist and the Director of Toxicology and Occupational Health at CTEH®, an environmental consulting firm headquartered in North Little Rock, Arkansas. Dr. Nony is board certified in Industrial Hygiene and as a Safety Professional and has over 20 years of training and

professional experience in the fields of toxicology, chemical emergency response, public and worker health and safety, and response planning. He received his Ph.D. in Toxicology from the University of Arkansas for Medical Sciences and spent two years in a postdoctoral fellowship at the National Institute of Environmental Health Sciences. Since joining CTEH in 2003, he has responded to hundreds of emergency situations involving the release of chemicals to the environment and performed evaluations of impacts to people and the environment. During emergency responses, Dr. Nony leads teams of scientists who characterize and communicate the extent of chemical hazard and other safety impacts to workers, communities, and the environment while assisting industry, agency, and community stakeholders alike to make decisions during disaster recovery and risk mitigation.

PROFILE OF DR. RAKESH DUBEY



Dr. Rakesh Dubey's education includes a bachelor's degree in Chemistry, Botany, and Zoology from Bundelkhand University (1977), and master's degree in Chemistry from Vikram University (1979). He has also obtained a Master of Philosophy degree in Chemistry (1980) and a Ph.D. in Chemistry (1994), both from Vikram University. He holds various course certifications in Environmental Impact Assessment and Auditing, Environmental Management, and Environmental Planning from reputed global institutions, and has participated in the 2010 United Nation's Conference on Disaster Reduction in Kobe, Japan.

His rich experience includes involvement in capacity development for various stakeholders of state and national agencies notably, as a project and senior research officer for Environmental Planning and Coordination Organisation (EPCO) the Government of Madhya Pradesh from 1982-1996; member of the Working Group Committee constituted by the Central Pollution Control Board (CPCB) in June 1994 for the drafting of Guidelines for the Preparation of Zoning Atlas for Sitting of Industries at the district level; and preparation an Environmental Management Plan (EMP) for the Chirimiri open cast mines of Southeastern coal fields in Chhattisgarh State. He has also been nominated as an expert member by the Housing and Environment Department of Madhya Pradesh for Industrial Health and Safety committees.

Dr. Dubey was deputed as Joint Director at the Disaster Management Institute (DMI), Government of Madhya Pradesh, Bhopal and as Director from August 2004. Thereafter, as Director of DMI from August 2004, he led disaster risk reduction and worked with the

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National Disaster Management Authority (NDMA), the Planning Commission for the Government of India, MOEF&CC, and PNGRB, Government of India. In 2007, the NDMA nominated him as a core group member for producing the “National Guidelines of Chemical/Industrial Disaster Management” and in 2010 designated him as the coordinator for making guidelines on “Strengthening of Safety and Security for Transportation of POL Tankers”. Not only has he provided leadership to establish the DMI, Bhopal, he has also providing training to NDRF and 101 Chief Judicial Magistrates (CJMs)/District Registrars, which has been his notable contribution to the country in the area of chemical/industrial disaster management. Besides, various states’ officers of Chief Inspectorates of Factories/Directorates of Industrial Health and Safety/DOF have been also trained under his leadership at the Disaster Management Institute, Bhopal.

Besides the above, he have provided leadership in making On-site and Off-site emergency management plans to various hazardous industries and districts respectively of various states of India, and has carried out safety audits, risk assessments and mock drills with the NDMA.

ANNEXURE - C

**EXPERT OPINION ON ROOT CAUSE ISSUES OF
THE STYRENE VAPOUR RELEASE INCIDENT
AT LG POLYMERS PLANT ON 7 MAY 2020**

BY

DR. HARRI K. KYTOMAA

DR. MICHAEL STERN

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Re: Scope and Limitations

1. At the request of Shardul Amarchand Mangaldas & Co., Exponent, Inc. (Exponent) performed an analysis of the styrene vapour release that occurred on 7 May 2020 in Visakhapatnam, India from Tank M6 at the LG Polymers facility.
2. The scope of this report includes responding to the findings and conclusions of the National Green Tribunal (NGT) Interim and Final Reports. Exponent did not perform an analysis to identify lessons learned, suggest modifications to future systems and procedures, or identify safety issues unrelated to the release.
3. This report is based, in part, on Exponent's review of the available documents related to the LG Polymers facility. The findings provided are to a reasonable degree of scientific certainty based on the information currently available. We reserve the right to modify or amend these findings if additional information becomes available.

Re: Qualifications**Dr. Harri Kytömaa**

Dr. Kytömaa is Group Vice President and Principal Engineer at Exponent and a Fellow of the American Society of Mechanical Engineering. He has a Ph.D. from the California Institute of Technology. He was Associate Professor of Mechanical Engineering at the Massachusetts Institute of Technology, where he was head of the Fluid Mechanics Laboratory. Dr. Kytömaa specializes in the engineering and analysis of thermal and flow processes. He applies his expertise to the investigation of major industrial accidents including losses of containment, spills and leaks, and resulting fires and explosions. He has investigated major industrial accidents that involved the formation of dense gas clouds that resulted in large fires and explosions, including the Skikda LNG facility explosion in Algeria (2004) and the Buncefield Fuel Depot fire and explosion in the UK (2005). He also routinely performs modelling and analyses of the behaviour of dense gas clouds and their dispersion in the context of regulatory approvals for the construction of new industrial facilities.

Dr. Michael Stern

Dr. Stern is a chemical engineer in Exponent's Thermal Sciences Practice. He has a Ph.D. in chemical engineering from the Massachusetts Institute of Technology and is a licensed Professional Engineer in chemical engineering in two states in the United States. Dr. Stern has experience in failure analysis, oxidation-reduction reactions of conjugated cyclic diones including quinones and catechols (such as TBC), chemical kinetics and thermodynamics of reactive and energetic materials including styrene monomer, and mass transfer behaviour and vapour-equilibrium of chemicals and mixtures. Dr. Stern is a

member of the ASTM E27 committee related to the testing and evaluation of the hazard potential of chemicals as well as NFPA 496 committees regarding the electrical classification of equipment in hazardous atmospheres. Dr. Stern has evaluated a number of chemical releases, fires, and explosions from chemical and petroleum facilities.

A. Re: Summary of Findings

4. The release originated from a styrene tank, Tank M6, at the LGPI facility due to exothermic auto-polymerization and resulting boiling of the styrene within the tank. The release occurred 45 days after a lockdown was imposed by the Indian government in response to the Covid-19 pandemic. The lockdown prevented normal operation and activity at the plant, which led to unprecedented stagnation in the LGPI styrene tanks and consequently increased the susceptibility of the stored styrene to auto-polymerization. LGPI maintained protocols that included temperature monitoring, inhibitor concentration monitoring, and daily operation of the refrigeration system to manage the risk of auto-polymerization.
5. Following these protocols, the tank M6 temperature and inhibitor levels showed no deviations or signs of auto-polymerization up through the time of the accident. Given that the temperature and inhibitor levels (the industry's widely used principal indicators) remained at the desired levels and the polymer content had stabilized, there was no signal or warning of uncontrolled auto-polymerization, tank rupture, or explosion.
6. During the early morning hours of 7 May, the LGPI control room was alerted by multiple styrene gas alarms surrounding Tank M6. Gas vapours were venting from the tank into the atmosphere. The alarms system functioned effectively and alarmed just one minute after the plumes were visible on the CCTV footage. LGPI personnel alerted fire and ambulance providers as well as their superiors. Several LGPI employees, wearing self-contained breathing apparatus (SCBAs), activated the water sprinklers and refrigeration systems for Tanks M5 and M6 in an effort to reduce the vapours and cool the tank and its contents. As a result of their actions and the design of Tank M6 and its ancillary equipment, no explosion or fire occurred and the vapours dissipated.
7. The auto-polymerization that led to the styrene vapour release occurred due to unprecedented and prolonged stagnation in Tank M6. The root cause of the prolonged stagnation was the forced sudden and prolonged shutdown of plant operation due to the restrictions of the Covid-19 lockdown.
8. Based on the currently available information, the specific sequence of events that led to the auto-polymerization within the stagnant region of Tank M6 cannot be determined.

9. Allegations that the root cause “appears to be lack of experience of LG Polymers India...in monitoring and maintaining full tanks of styrene that were idled for a long period of several week without operation” are unfounded, incorrect, and without merit.

B. Re: Background on the Design and Operation of the LGPI Facility and Tank M6

10. LG Polymers India Limited (LGPI) is a manufacturer of polystyrene products. Specifically, LGPI’s Visakhapatnam, India facility includes three polystyrene plants: General Purpose Polystyrene (GPPS), Expanded Polystyrene (EPS), and High-Impact Polystyrene (HIPS).
11. The primary feedstock for these three plants is liquid styrene monomer. For the GPPS and EPS plants, the styrene monomer is stored onsite in running tanks M5 and M6. During normal operation, the running tanks receive multiple deliveries per day from tanker trucks and are constantly discharging styrene to the plants. Because of the frequent additions and withdrawals during normal operation, the material in the running tanks is well mixed and regularly refreshed with new material.
12. Styrene is received by ship twice per month at the nearby port facility. From the port, the styrene is transferred via a cross-country pipeline to two shore tanks leased from Eastern Petroleum India Limited (“EIPIL”) by LGPI (Tanks 102 and 123). The styrene in the shore tanks is then transported incrementally to Tanks M5 and M6 by dedicated tanker trucks on a near daily basis to maintain inventory at the plant.
13. Styrene in storage slowly generates reactive species known as free radicals. These free radicals would cause the styrene to auto-polymerize if not controlled. The industry standard practice for controlling free radicals is to add a small concentration of inhibitor.¹
14. The most common inhibitor, and the one present in the styrene at LGPI, is para-tertiary butyl catechol (TBC). Industry guidance recommends a concentration of 10-15 parts per million (ppm) of TBC be maintained. If the concentration drops below 4 ppm, auto-polymerization will no longer be controlled.² As the

¹ Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 9. (relevant extracts enclosed herewith as **Appendix 1**)

² For example see Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, pp. 15, 40. TBC requires oxygen to operate. Oxygen reacts with the free radicals to form peroxides, which then are neutralized by the TBC. The concentration of oxygen required for TBC to function (about 5 ppm) is only 10% of the concentration of oxygen that would be present in styrene in equilibrium with air. Styrene in contact with air, therefore, has substantially more oxygen than required for TBC to inhibit auto-polymerization. When oxygen is consumed to form a peroxide, TBC is also consumed to neutralize that peroxide. Therefore, oxygen depletion and TBC depletion are linked. When TBC concentrations are in the recommended range of 10-15 ppm, oxygen depletion due to reaction with free radicals will not occur without TBC depletion.

TBC controls the auto-polymerization, it is slowly consumed. Industry guidance suggests that additional TBC is only recommended to be added if the TBC concentration drops below the 10-15 ppm range. Industry guidance indicates it requires approximately two months of storage at 25°C for the TBC concentration to decrease from 15 ppm to 10 ppm.³

15. The need for temperature control through insulation and/or refrigeration in a styrene tank is dependent on the intended length of storage (also known as the residence time), the ambient conditions, and the initial TBC concentration. Based on industry guidance, not all tanks require insulation and/or refrigeration for safe operation.⁴ In some cases, insulation and refrigeration may be added to improve the quality of styrene even if it is not necessary for safe operation.
16. During normal operation and the lockdown, LGPI regularly monitored the concentration of TBC. Due to the short storage times of styrene during normal operation as it was continuously used in the day to day production, TBC depletion was minimal and no additional TBC was required.
17. Based on the residence times of styrene in storage, the temperature of storage, and the TBC concentration in the delivered styrene, refrigeration of tank M6 was not necessary to maintain TBC at the concentrations recommended by industry guidance. However, LGPI chose to install insulation and refrigeration for both Tank M6 and Tank M5 to maintain monomer quality.
18. During normal operation and the lockdown, LGPI monitored the status of Tank M6 with temperature measurements at two elevations in the tank. At one location, the temperature was continually monitored using a temperature sensor connected to the facility's central control system.⁵ At a second location,⁶ LGPI also monitored the incoming and outgoing temperatures for the styrene from the chiller one or more times per day to monitor the performance of the refrigeration system.
19. LGPI also continuously monitored the level of the tank through a level sensor connected to the facility's central control system and through physical measurements via a dip hatch. The dip hatch is an 8-inch diameter opening in the roof of the tank, through which a stainless-steel measuring tape can be lowered into the tank to physically measure the liquid level. The dip hatch is

³ Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 15.

⁴ Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 55.

⁵ The temperature is recorded under equipment tag O-TI-104.PV and has been exported to "03_2020_M6 Tank.csv", "04_2020_M6 Tank.csv", and "05_2020_M6 Tank.csv"

⁶ For example, SMH log (6th May) indicates that the temperature of the styrene leaving the tank and flowing towards the chiller was 16.5°C on 6 May 2020. The inlet location is shown graphically in Figure 3.

fitted with a rain canopy to allow air to freely flow in and out of the tank but prevent rain from entering.⁷

20. During normal operation and the lockdown, LGPI performed regular sampling of the styrene monomer in the tank M6 to measure the concentration of inhibitor in the tank, the amount of polymer in the tank, and the colour of the styrene. There was no indication of an imminent safety problem in any of the available data prior to the release on 7 May 2020.⁸ The available level and temperature data is shown in Figure 1 while the available TBC and polymer data is shown in Figure 2.

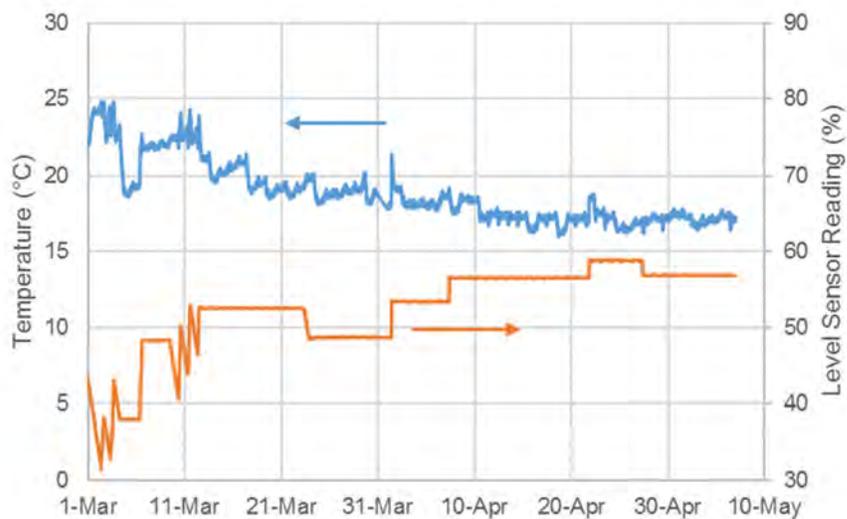


Figure 1. Temperature (blue) and level (orange) measurements from 1 March 2020 through 6 May 2020.

⁷ Drawing of the M6 Tank as provided by LGPI (enclosed herewith as **Appendix 2**)

⁸ Tank M6 DCS data for the lockdown included equipment tags O-TI-104.PV (temperature), O-LI-135.PV (level), and O-VOC-143.PV (VOC) provided in "03_2020_M6 Tank.csv", "04_2020_M6 Tank.csv", and "05_2020_M6 Tank.csv"; TBC, polymer, and color data were recorded in the 2020 Styrene Logbook (of LGPI).

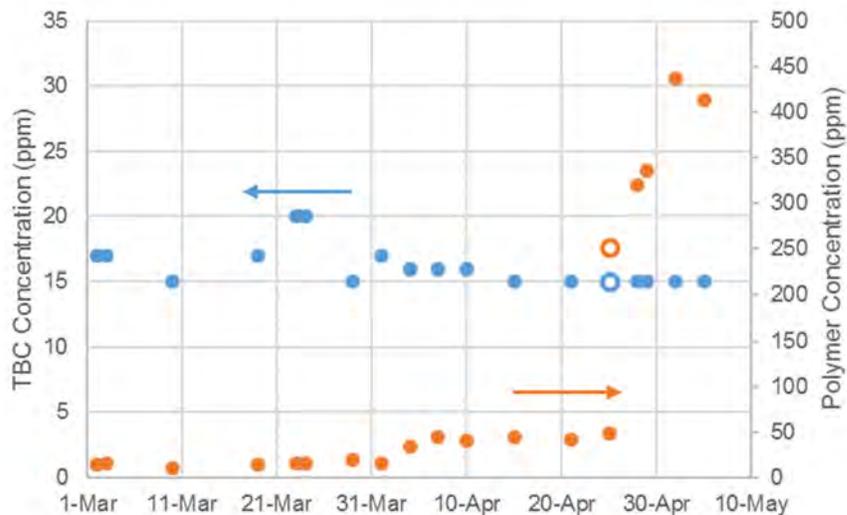


Figure 2. Measured TBC (blue) and polymer (orange) concentrations from 1 March 2020 to 5 May 2020. Measurements taken at the top of the tank are shown as open circles where measurements from the bottom of the Tank are shown in filled circles.

21. While LGPI possessed a procedure for TBC addition into the tanks, TBC addition had not previously been necessary due to the short residence times of storage that result from continuous operation.⁹
22. The EIPL shore tanks do not possess insulation, refrigeration, or circulation. Therefore, the primary methods of minimizing polymerization of the styrene are limiting the residence time of the styrene to 2-3 weeks through continuous operation of the LGPI facility and regular monitoring of the styrene temperature, TBC content, and polymer concentration. Because the EIPL shore tanks do not possess refrigeration or insulation, the styrene is warm when it arrives at the LGPI running tanks, Tanks M5 and M6.
23. Tank M6 used a dip pipe arrangement for the refrigerated styrene being returned, which was an effective and appropriate design. This design minimized the potential for static electric discharges (an ignition hazard) and also focused the refrigeration to the bottom of the tank where the tank received the warm styrene transported from the shore tanks (as shown in Figure 3). The warm styrene from the shore tanks represented the greatest heat source into the tank by an order of magnitude when compared to heat from ambient warm air or sunlight, and, as a result, the placement of the dip pipe near the primary source of heat was sensible and effective.

⁹ LGPI's SOP - TBC Chemical addition (enclosed herewith as **Appendix 3**)

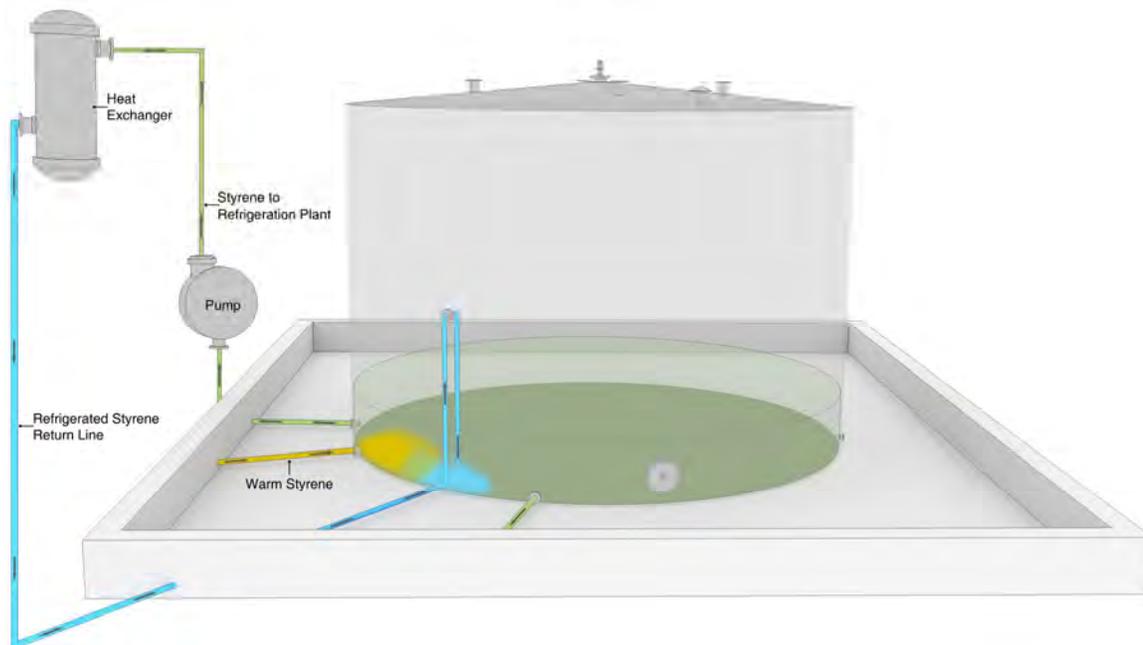


Figure 3. Diagram showing the relative locations of the refrigerated styrene discharge (blue) and the warm styrene inlet (yellow).

24. The addition of warm styrene into the bottom of the tank will create temporary temperature and density inversions (where the density at the top of the tank is greater than at the bottom) that will enhance mixing due to buoyancy driven flows.
25. Tank M6 was intended to always be used with regular deliveries and outflows. Operation without regular deliveries and outflows leads to stagnation.

C. Re: Sequence of Events prior to the Release

26. As of 22 March 2020, approximately one week supply of styrene monomer (2,487 metric tons) was in LGPI running tanks onsite with an additional two and half weeks supply (7,125 metric tons) in the EIPL shore tanks and 6,242 metric tons already enroute from South Korea to be delivered 4 weeks later.¹⁰ This was an appropriate amount of stored styrene to support the normal production at the facility given that deliveries occur every 2-3 weeks.
27. On 22 March 2020, LGPI learned of the lockdown order G.O.Rt.No.209 issued by the Andhra Pradesh government that indicated they would need to shut down their polymerization plants until 31 March unless granted permission from the District Collector and Magistrate to keep operating. Specifically, the order

¹⁰ Values provided by LGPI. LGPI was able to cancel a shipment for earlier in April as it had not yet departed.

exempted “Manufacturing Units which require continuous process may continue to function, after obtaining required permission from the Collector.”¹¹

28. On 23 March 2020, LGPI warned the District Collector and Magistrate of Visakhapatnam (“District Collector”) of the risk of auto-polymerization and explosion.¹² LGPI sought for the District Collector’s permission to continue limited polystyrene production to mitigate the identified risk of auto-polymerization.
29. On 24 March 2020, the Ministry of Home Affairs and the Govt. of Andhra Pradesh published guidelines that also included an exception for industrial establishments with “production units, which require continuous process, after obtaining required permission from the State Government”.¹³ LGPI’s polystyrene production did require continuous operation to prevent styrene monomer stagnation. However, the request by LGPI to operate the plants was not granted by the District Collector despite meeting the requirements for this exception.
30. LGPI sent another letter dated 28 March 2020 to the District Collector requesting sixty emergency passes to deploy staff at the plant 24/7 to monitor the styrene and other hazardous materials stored onsite.¹⁴ In response, forty-five passes were provided by the District Collector for LGPI to maintain and monitor the facility (polystyrene production was not permitted). Thus, only 15 employees were allowed to enter the plant premises and monitor the facility per shift as against around 50 employees (day shift) during normal operations.
31. Given the limited nature of operations permitted by the District Collector, LGPI prepared an operating procedure that included operating the refrigeration system, continuously monitoring temperature, and regularly measuring styrene polymer concentrations and styrene inhibitor levels in each tank.¹⁵ Tank M6 temperature measurements, shown in Figure 1, showed no sign of auto-polymerization and inhibitor levels, shown in Figure 2, remained well within the accepted range for styrene storage throughout the 45-day lockdown period.
32. Operation of the refrigeration system was performed for one shift a day (approximately 8 hours) and documented in the SMH Patrol logbook.¹⁶

¹¹ G.O.Rt.No.209 dated 22 March 2020 issued by the Govt. of Andhra Pradesh (enclosed herewith as **Appendix 4**)

¹² Letter to District Collector dated 23 March 2020 issued by LGPI. (enclosed herewith as **Appendix 5**)

¹³ Separate Government Orders dated 24 March 2020 issued by the Govt. of Andhra Pradesh and Ministry of Home Affairs (enclosed herewith as **Appendix 6**)

¹⁴ Joint Collector letter request for 60 passes (28th March 2020) issued by LGPI (enclosed herewith as **Appendix 7**)

¹⁵ Lockdown SOP dated 1 April 2020 (enclosed herewith as **Appendix 8**)

¹⁶ The times when the refrigeration and circulation in Tank M6 was started and ceased each day is recorded in the logbooks maintained by the SMH operators known as the Patrol logsheet. For

33. On around 20 April 2020, LGPI planned to again ask the authorities to allow for operation of the facility at reduced capacity. On 21 April, an LGPI representative attended a meeting held by the District Collector. During that meeting, it was made clear that LGPI's request would not be granted because LGPI was not deemed an essential service and the District Collector would not provide special permissions for non-essential services. As a result, LGPI continued to monitor the styrene without the ability to undertake normal operations.
34. Also on 21 April, LGPI received a shipment of 6,242 MT of styrene at their shore tanks at EIPL that they could not refuse as the shipment had set sail prior to the lockdown.¹⁷ As part of the quality measurements of the styrene, 73 MT of styrene were brought to LGPI and transferred to Tank M6.
35. Starting on 25 April, an elevated polymer concentration of 252 ppm (0.0252% of the total mass of stored material in the tank) was detected at the top of the styrene liquid in Tank M6. An increase in polymer content at the bottom of the stored styrene liquid was observed on 28 April. The concentration reached a maximum of 437 ppm (0.0437%) on 2 May.¹⁸
36. Such sudden increases had been previously observed and were considered to be a quality issue (dissolution of polymer deposits that had accumulated within the tank that can cause discoloration or haziness in the final polymer product). Such sudden increases in polymer concentration as a result of polymer dissolution are also well-documented in styrene industry literature.¹⁹ Because the inhibitor level and temperature remained in the desired range during the entire lockdown period, there was no indication of auto-polymerization.
37. Occasionally, LGPI did experience polymer concentrations levels above normal, for example in 2019, polymer concentration increased to as high as 364 ppm and fluctuated around 300 ppm for the month of August as shown in Figure 4. No depletion of TBC or other adverse safety implications were observed along with the prolonged increase in polymer concentration at that time.

example, on 6 May 2020, the Patrol logsheet indicates the refrigeration and circulation was started at 8:30 AM and stopped at 4:00 PM.

¹⁷ Analysis Report -Styrene shipment (Hanwha)- 21 04 2020 (enclosed herewith as **Appendix 9**)

¹⁸ See Figure 2

¹⁹ Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, pp. 41-42.

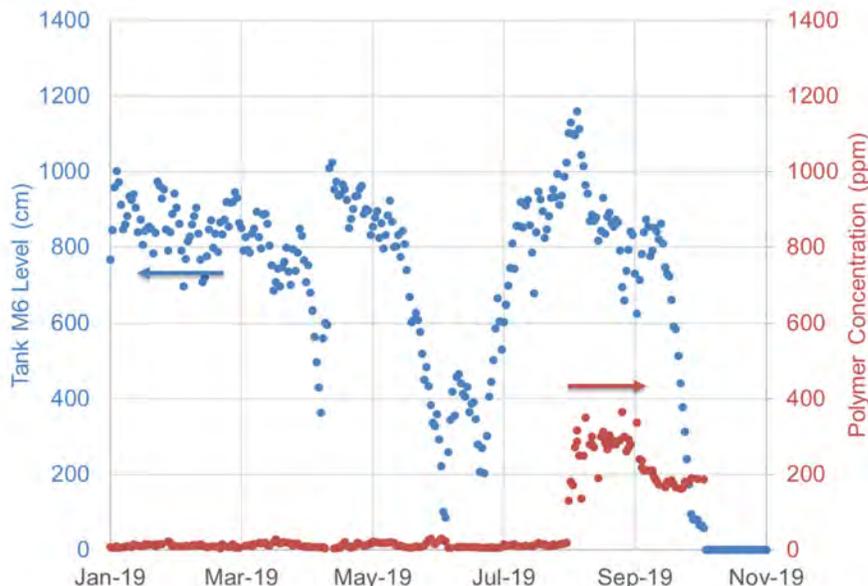


Figure 4. Tank level per dip measurements (blue) and polymer concentration (red) in 2019 showing rise in polymer content in August and September.²⁰

38. By 5 May the Tank M6 polymer concentration had stabilized and started decreasing.²¹ The stabilization and reduction of the polymer concentration further indicated that the rise in polymer concentration during the week from 25 April to 2 May was due to dissolution of polymer that had previously deposited on tank surfaces (a temporary event) and not auto-polymerization within the tank, which would be a progressive and accelerating event.
39. Based on the exothermic nature of styrene monomer auto-polymerization, the formation of 10,000 ppm (1%) of polymer will induce a 2-3°C rise in temperature.²² Therefore, polymer concentrations in the hundreds of ppm represent a negligible source of heat and would not indicate the formation of high temperatures. Industry guidance also suggests that “[a] 2-3°C/day temperature increase is a typical indication of the onset of a runaway polymerisation.”²³ Based on the relationship of temperature and polymer concentration, that means that a polymerization rate of 10,000 ppm per day is indicative of a runaway reaction. The rates of polymerization at LGPI were

²⁰Dip measurements based on Patrol logbook from 2019; Data provided by LGPI.

²¹ See Figure 2.

²² Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 42.

²³ Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 40.

approximately 100 times less than this rate, and therefore, did not indicate runaway polymerization.

40. Therefore, the findings in the NGT Final Report at Section 6.b indicating that auto-polymerization started on April 20 are incorrect and contradicted by the available evidence.²⁴
41. The Tank M6 temperature and TBC inhibitor levels showed no deviations or signs of auto-polymerization up through the time of the accident. Given that the temperature and inhibitor levels (the industry's widely used principal indicators) remained at the desired levels and the polymer content had stabilized, there was no signal or warning of uncontrolled auto-polymerization, tank rupture, or explosion.
42. Based on the conditions at the top of the tank, the inhibitor should have remained at recommended levels through May and prevented auto-polymerization through June. The LGPI plant personnel were intending to start operation on 7 or 8 May 2020.

D. Re: The Styrene Vapour Release

43. In the early morning hours of 7 May 2020, there was a sudden unanticipated auto-polymerization in Tank M6, resulting in a release of styrene monomer vapour through the vents at the top of the tank.
44. There were no indications in the data available to LGPI that would have suggested auto-polymerization was occurring in Tank M6 prior to the styrene vapour release. At the time of the release, five events occurred in quick succession:²⁵
 - a. A sudden increase in pressure in the tank (as evidenced by the pressure-based level sensor) occurred at 2:55 AM IST,²⁶
 - b. The visual appearance of vapours venting from the top of the tank on CCTV surveillance video occurred at approximately 2:57 AM IST;
 - c. Triggering of gas detectors located at the base of the tank occurred at 2:58 AM IST;

²⁴ Final Report of NGT Committee, 28 May 2020. p. 15

²⁵ Based on three equipment tags O-TI-104.PV (temperature), O-LI-135.PV (level), and O-VOC-143.PV (VOC) provided recorded by the DCS system and provided by LGPI in "05_2020_M6 Tank.csv", CCTV footage, and the DCS recorded alarm history provided by LGPI in "Gas Detector Alarm History.pdf" (relevant extract of Gas Detector Alarm enclosed herewith as **Appendix 10**)

²⁶ The level sensor operates by measuring the pressure near the bottom of the tank and converting to an approximate level. The level is approximate because it requires an assumption of density and is subject to errors if solid materials form and sink in the tank.

d. A sudden increase in the reading from the volatile organic compounds sensor (which can detect styrene among other organic vapours) located in the styrene unloading area at 3:01 AM IST.²⁷

e. An increase in temperature in the tank was observed at 3:04 AM IST.

None of these events were present the night before the incident or even a few minutes before the incident.

45. At 2:57 AM IST²⁸, the vertical plume was barely perceptible in the CCTV footage. A series of images captured from the CCTV footage is shown in Figure 5. At 2:58 AM, the vertical plume became more discernible than at 2:57 AM but was still less persistent than at 3:09 AM and 3:20 AM when the plumes appear similar. This indicates that the plume at 2:57 AM was primarily air and that the styrene concentration of the plume increased between 2:57 AM and 2:58 AM and then again between 2:58 and 3:09. This occurred because the initial ambient air in the approximately 1,000 m³ headspace was displaced by styrene as the release progressed.

²⁷ Note that the value initially exceeds the sensor maximum of 1,000 ppm starting at 2:57:59 AM DCS until 3:02:44 AM DCS when the value drops to 996 ppm.

²⁸ Note that the CCTV time is 16 minutes behind IST. Therefore, 2:41 AM on the CCTV indicates 2:57 AM IST. This includes a 12 minute difference between the CCTV and DCS (DCS is 12 minutes ahead of CCTV) and a 4 minute difference between the DCS and IST (IST is 4 minutes ahead of DCS). This can be confirmed based on comparing the times in which the pressure spike in the DCS data occurs (2:51 AM DCS or 2:55 AM IST) and the first images showing a faint plume in the CCTV system (2:41 AM CCTV or 2:57 AM IST).



Figure 5. Images of release starting at 2:57 AM IST. IST is 16 minutes ahead of CCTV time.

46. The lack of any prior signs of the polymerization, the low concentration of styrene in the initial plume, and the rate of styrene vapour formation all suggest a localized region of the tank rapidly heated. The data is not consistent with a slow heating of the tank due to thermally initiated auto-polymerization.
47. Therefore, the findings in the NGT Final Report at Section 6.b indicating a slow and steady growth of a hotspot are incorrect and contradicted by the available evidence.²⁹
48. The reaction also led to a sudden increase of pressure in the tank, which caused a separation at the weld-seam between the tank roof and the tank wall. This separation relieved the pressure inside the tank preventing a catastrophic

²⁹ Final Report of NGT Committee, 28 May 2020. p. 15

rupture of the tank. Styrene vapour continued to vent through the open vents and the weld-seam separation.

49. An analysis of the CCTV footage and satellite imagery available from the time of the release indicates that the release from the weld-seam was directed towards the northwest of Tank M6.³⁰ The wind direction was toward the northwest.

E. Re: LGPI Response to the Release

50. LGPI responded to the release by, among other measures, activating the sprinklers, adding polymerization inhibitor and retarder chemicals, and draining of styrene to other tanks. The design of the LGPI facility, including the M6 tank, and the actions taken by LGPI prevented a catastrophic rupture of the M6 tank, and prevented ignition of the styrene vapours and an explosion.
51. As the reaction was focused at the top of the tank, mitigating the reaction at this time was not possible through addition of inhibitor or diluent via the day tank, operating the chiller, or draining styrene to another tank because those mitigation methods primarily impact the bottom of the tank. There were no additional activities LGPI could have reasonably undertaken that would have mitigated the initial release.
52. After approximately 3:50 AM IST, the emissions dramatically slowed after a loss of a few percent of the styrene level in Tank M6. The small change in level during the initial release suggests the initial release occurred as a result of a localized phenomenon that impacted a small volume of the tank and not due to a slow progressive deterioration of the storage conditions within the tank.
53. The fire protection system for Tank M6 was designed with quartzoid bulbs that activate the deluge sprinkler system if the bulbs are exposed to 68°C or greater.³¹ As no fire or explosion occurred and the hot vent gases did not directly impinge on one of the quartzoid bulbs, the deluge system was not automatically triggered. While operation of the sprinklers may have provided a local benefit of reducing the styrene concentration close to the tank, they are designed to mitigate fire and explosion hazards and not stop a vapour release.
54. At approximately 4:30 AM IST several mitigation activities were undertaken included initiating the sprinkler system, the refrigeration system, injecting antioxidant chemicals, chain transfer agents (as inhibitors) and water, and draining about 95 MT of styrene from M6 to three other tanks. Approximately

³⁰ Satellite images accessed using Google Earth.

³¹ Based on specifications on sprinkler system as provided by LGPI.

70 MT was gravity drained to Tank 1221A, 10 MT to the GPPS Feed Preparation Tank (FPT), and 15 MT to the GPPS Feed Solution Tank (FST).³²

55. Throughout the day, approximately 2,348 kg of inhibitor and retarder chemicals were added.³³ These chemicals – due to their ability to scavenge and consume free radicals, or slow the free radical reactions – would have halted the reactions occurring in the cooler parts of the tanks.

56. In addition to the inhibitor, water was also injected into the top of the tank via the foam pourer. Due to the significant energy required to heat and evaporate water to steam, the addition of water cools the contents of the tank and reduces the available energy for evaporation of styrene.

F. Re: Response to Allegations regarding the Design and Operation of Tank M6

Recommended Storage Conditions

57. In their Final Report, the NGT makes inaccurate statements regarding the temperature at which styrene should be stored. They state that “[i]f the temperature approached 20°C the tank must be cooled and under no circumstances the temperature should exceed 25°C.”³⁴ No reference is cited for this statement.

58. Industry guidance contradicts the NGT’s claims. The PlasticsEurope guideline says the temperature would be “preferably” below 25°C, but does not state that the temperature should not exceed 25°C as claimed.³⁵ The Chevron handling guide includes a table (reproduced in Figure 6) that indicates how often various measurements should be made during storage that explicitly includes scenarios with temperatures that exceed 26.7°C. During normal operation the temperatures were maintained around 25°C.

³² Based on a review of DCS data for equipment tags G-LI-108.PV (FST Tank Level), G-LI-103.PV (FPT Level), and O-LI-132.PV (1221A Tank Level). A dip measurement of 168.2 cm for Tank 1221A recorded in the Patrol logsheet on 9 May 2020 was also considered.

³³ See LGPI’s Inhibitors stock register May 2020 that indicates the amount of different inhibitors consumed in May. As the plant was shut down, consumption only occurred as a result of the response to the styrene vapor release. TBC addition occurred later and is not considered in the total. An additional 100 kg of hydroquinone was also added but was taken on loan basis from M/S SNF Polymers. (enclosed herewith as **Appendix 11**)

³⁴ Final Report of NGT Committee, 28 May 2020. p. 14

³⁵ Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 47.

**Suggested Testing Schedule for
Styrene Bulk Storage**

Monomer Temperature	Frequency	Key Properties
26.7°C (80°F) or higher	Weekly	Polymer ASTM D2121 Inhibitor ASTM D4590
21.1 - 26.1°C (70 - 79°F)	Bi-weekly	Color ASTM D5386 or D1209 Appearance Visual
Below 21.1°C (70°F)	Monthly	Aldehydes ASTM D2119 Peroxides ASTM D2340

Figure 6. Table 2B from the Safe Handling and Storage of Styrene Monomer, Chevron Phillips Chemical Company, L.P, September 2010.

59. Industry guidance also contradicts the NGT's assertion that the tank must be cooled if "the temperature approached 20°C". Specifically, PlasticsEurope indicates that the insulation and refrigeration are required if "*extremely high temperatures are likely to be encountered.*"³⁶ Further, Americas Styrenics and Chevron state that "[m]ost consuming locations insulate storage tanks to dampen the effect of high day time temperatures but do not install refrigeration due to cost."³⁷ LGPI, therefore, exceeds the industry practice by installing both refrigeration and insulation in Tank M6.
60. The NGT also asserts without basis in their Interim Report that "[t]here need to be continuous circulation to prevent settling of TBC."³⁸ No reference is cited for this statement.
61. During normal operation, Tank M6 was circulated frequently due to a combination of styrene additions and discharges and through its refrigeration system that recirculates styrene while chilling it in an external refrigeration loop as shown in Figure 3.

Liquid Temperature Measurement

62. The styrene polymerization reaction is exothermic and therefore there is the risk of thermal runaway that can result in an explosion or other hazards. To reduce the risk of thermal runaway, the Styrene Producers Association,

³⁶ Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 55.

³⁷ Safe Handling and Storage of Styrene Monomer, Americas Styrenics LLC, November 2016, p. 19; Safe Handling and Storage of Styrene Monomer, Chevron Phillips Chemical Company, L.P, September 2010, p. 22. (relevant extracts of Safe Handling and Storage of Styrene Monomer, Americas Styrenics LLC enclosed herewith as **Appendix 12**; relevant extracts of Storage of Styrene Monomer, Chevron Phillips Chemical Company, L.P, enclosed herewith as **Appendix 13**)

³⁸ Interim Report of NGT Committee, 17 May 2020. p. 6

Chevron Phillips, Americas Styrenics, and Shell Chemical recommend that the liquid styrene monomer temperature be monitored daily.³⁹

63. No specific guidance is provided for the minimum number of locations when the temperature is continuously monitored as in Tank M6. Tank M6 had one location where the liquid styrene monomer temperature was continuously monitored and recorded every minute (1440 times per day)⁴⁰ and a second location where it was checked one or more times per day.⁴¹ The locations of measurement were appropriate because Tank M6 was mixed by frequent additions and discharges during normal operation. The design and operation of Tank M6, therefore, was consistent with, and in some aspects exceeded, industry practice and was sufficient during normal operation.
64. The NGT Interim Report suggests without basis that vapour release was due to the fact that the "...the tank has no provision of monitoring storage temperature at top layers of the storage."⁴²
65. Similarly, the NGT Final Report states that the "leaked tank was old and does not have temperature sensors at middle and top surface of the tank except only provision to measure the temperature at the bottom of the tank where refrigeration is provided. Due to lockdown, the storage tank was stand still."⁴³
66. The NGT Interim Report, however, fails to provide any analysis or justification to demonstrate that additional monitoring locations would have provided sufficient warning of the release given the stagnant condition of the tank due to the lockdown. Thermal diffusion in stagnant tanks is a slow process and a hotspot would not be detected unless the sensor happened to be very close to the top liquid surface, which moves up and down during normal operations.
67. Moreover, the NGT Final Report's observation on the age of the tank has no relevance to the present case. Tank age alone is not a criterion for fitness of service and there is no evidence specific to the age of the tank that has been presented as a cause of the release. Hundreds of shell thickness measurements and three weld-joint assessments of Tank M6 had been

³⁹ Safe Handling and Storage of Styrene Monomer, Chevron Phillips Chemical Company, L.P., September 2010, p. 15; Styrene HSSE and Product Stewardship, Shell Chemicals, January 2011, p. 21; Safe Handling and Storage of Styrene Monomer, Americas Styrenics LLC, November 2016, p. 14; Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 13.

⁴⁰ See Figure 1.

⁴¹ For example, SMH log (6th May) indicates that the temperature of the styrene leaving the tank and flowing towards the chiller was 16.5°C on 6 May 2020. The inlet location is shown graphically in Figure 3.

⁴² Interim Report of NGT Committee, 17 May 2020. p. 11

⁴³ Final Report of NGT Committee, 28 May 2020. p. 14

performed in December 2014 to January 2015 and did not identify any issues with the tank.⁴⁴

68. To evaluate the NGT's claims, calculations were performed using a 1-D transient heat transfer model to evaluate the measured temperature at a hypothetical sensor located below a hot layer of liquid at the top of the tank. As the tank shell was approximately 12 meters tall, we assumed a middle temperature sensor would have been located approximately 6 meters from the base of the tank adjacent to the wall. The styrene liquid height was 8.377 meters based on last dip measurement made prior to 7 May 2020.⁴⁵ Therefore, this hypothetical middle temperature would have been located approximately two meters below a potential hot layer at the top of the liquid. For the analysis, a conservatively hot temperature of 85°C was chosen for the layer temperature. The results are shown in Figure 7.

⁴⁴ "M6 TANK MPT TEST_Jan2014.pdf" and "M6 TANK THICKNESS GAUGING_Dec2014.pdf". (copies enclosed herewith as **Appendix 14**)

⁴⁵ Based on the physical dip measurement made and recorded by SMH operators in the Patrol logsheet on 28 April 2020.

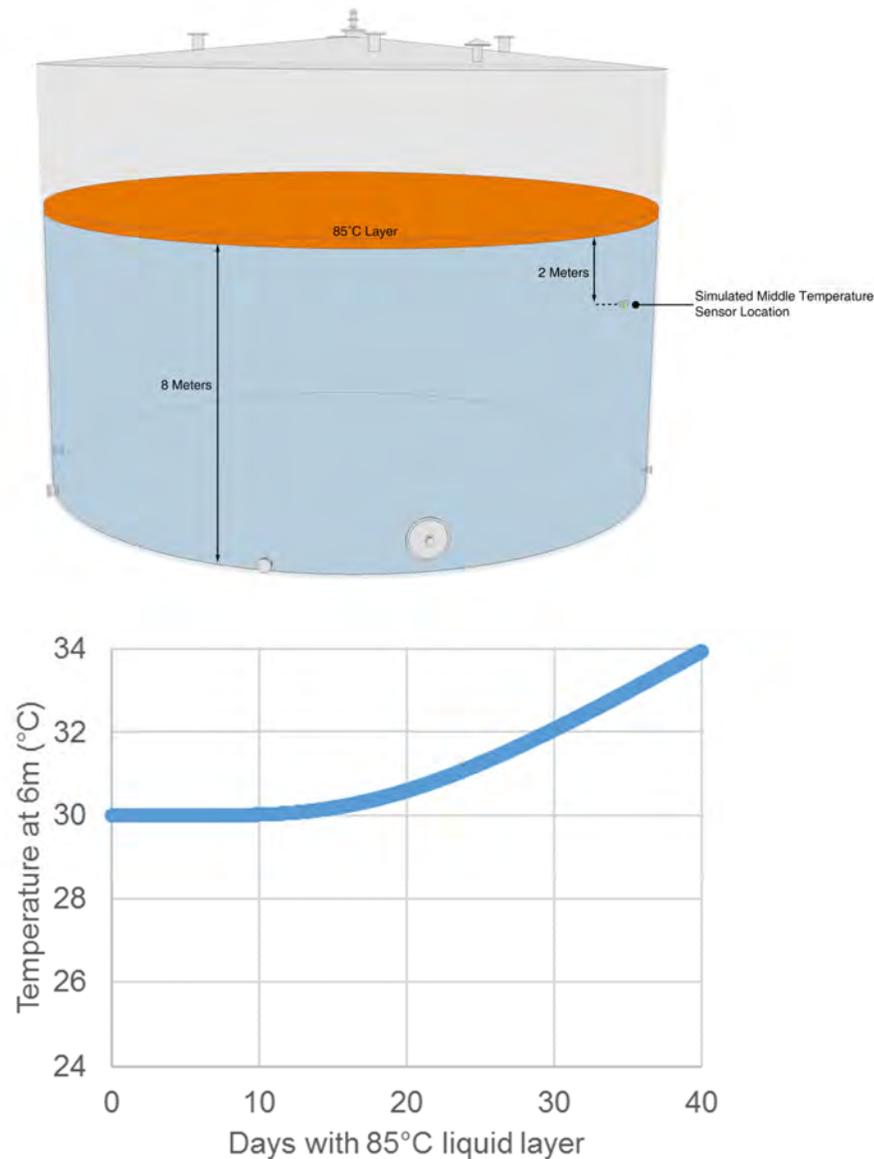


Figure 7. Diagram of simulated hot layer condition (top). Calculated temperature at a measurement location two meters below an 85°C hot layer in a styrene tank (bottom)

69. The results, shown in Figure 7, indicate that it would take approximately 30 days for a 2°C increase in temperature to be observed by the hypothetical middle temperature sensor from an 85°C hot layer located just two meters above it in a stagnant tank. For comparison, industry guidance recommends

action when a 2°C increase is observed in a single day.⁴⁶ Thus, the increase in 2°C over 30 days in this scenario would not be a cause for concern.

70. To analyse the impact of additional temperature sensors in the hypothetical scenario where a rapid polymerization occurs in a hot spot, rather than a hot layer, towards the top of the tank, a 2-D, axisymmetric, transient CFD model of the tank was developed using STAR-CCM+.⁴⁷ The model accounts for changes in material properties of styrene due to temperature and for buoyancy effects.
71. The CFD simulation is used to evaluate the ability for a hypothetical middle temperature sensor located 6 meters above the bottom and adjacent to the wall to detect an 85°C hotspot with a hemi-spherical geometry located in the top centre of a quiescent tank with a uniform initial styrene temperature of 30°C. The hotspot is assumed to have a 4.5-meter diameter (one quarter the diameter of the tank). A diagram of the considered scenario is shown in Figure 8 and the results of the simulation are shown in Figure 9 and Figure 10.

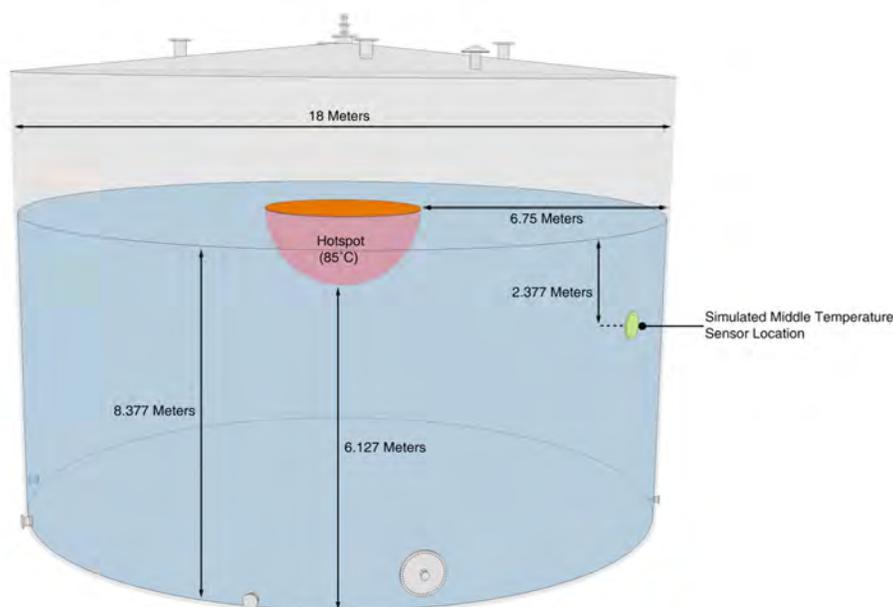


Figure 8. Diagram showing the conditions for the 2-D, axisymmetric, transient CFD model with top center hotspot.

⁴⁶ Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, pp. 40.

⁴⁷ For slow polymerizations, the 1-D transient model described in paragraph 7, above, is appropriate and sufficient because the warm styrene will flow towards the top of the tank and form a layer due to the lower density of warm styrene compared to cold styrene. For example, the density of 85°C styrene is approximately 5% less than that of 30°C styrene. For comparison, the density of cooking oils are about 10% less than that of water. The tendency for a hotspot of styrene to form a top layer in the tank will be similar to oil forming a top layer when added to water.

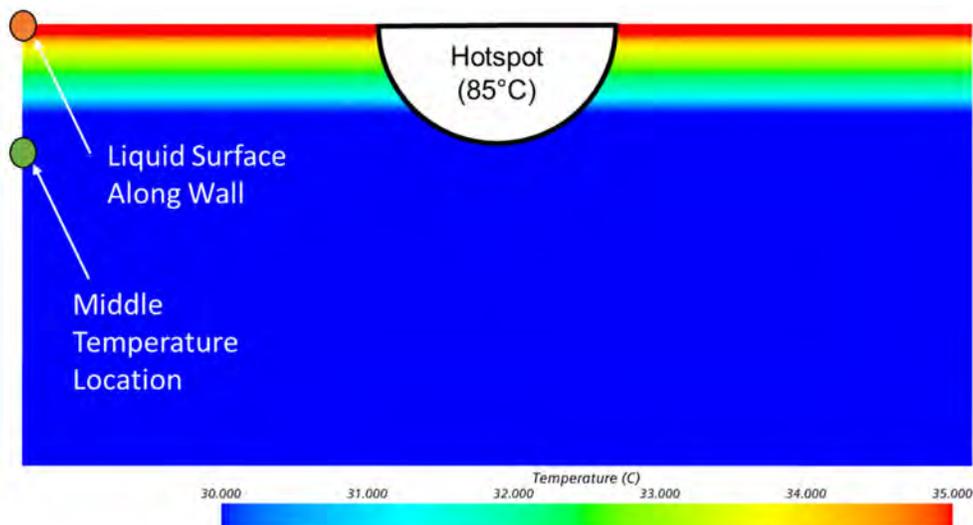


Figure 9. Simulation results (at 100 minutes after the initiation of the hotspot) of the temperature profile in the tank if a hemispherical hotspot forms at the top center of the tank.

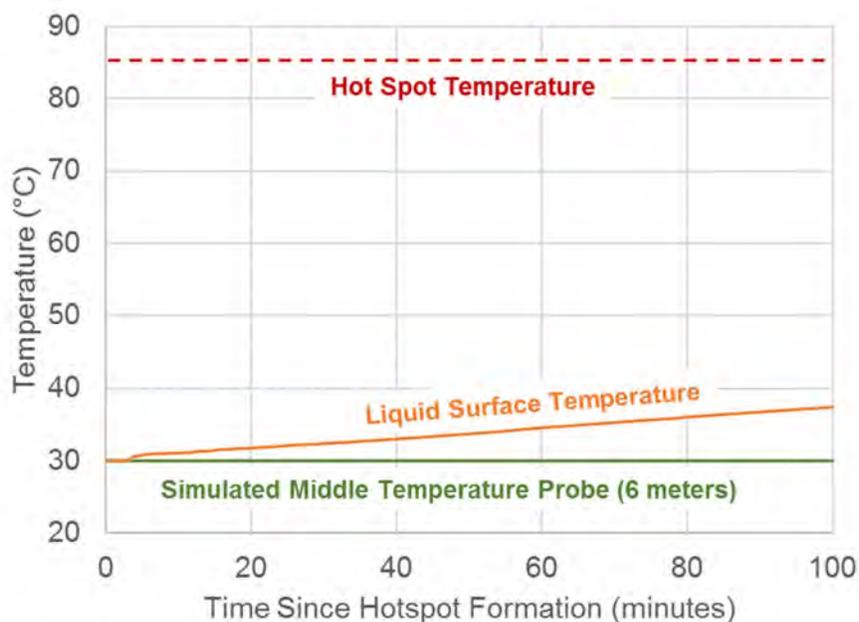


Figure 10. Calculated temperatures resulting from a hypothetical 4.5-meter diameter hot spot. Temperatures are shown at the top liquid surface along the wall and at the location of a simulated middle temperature sensor located 6 meters above the base of the tank along the wall.

72. The results indicate that while the hotspot could lead to heating at the very top of the liquid surface around the hotspot (the blue curve in Figure 10), the surface heat could not penetrate downward due to buoyancy and the slow rate of heat

conduction. Therefore, no temperature increase is observed at the hypothetical 6-meter sensor (orange curve in Figure 10). Based on this analysis, if rapid polymerization had initiated towards the top of the tank, an additional temperature sensor at a middle elevation of the tank would not have provided any warning.

73. Based on the analyses described above, had additional continuously monitored temperature sensors been present in Tank M6 during the lockdown, they still only would have provided additional useful information if they happened by chance to be located close to where the auto-polymerization was occurring (a location that has not been identified). Temperature sensors can only measure the temperature of the fluid in contact with the sensor and cannot detect temperatures of liquid elsewhere in the tank. As stated by the Styrene Producers Association, “[p]olymerisation can be ongoing and unnoticed in zones that are not near the thermocouple, if the tank contents are not well-mixed.”⁴⁸ Therefore, because of the unprecedented stagnation in the tank resulting from the lockdown prior to the incident, additional liquid temperature measurements would not have been effective at detecting localized regions of auto-polymerization, if they did occur.

Thus, the conclusion of the NGT Interim Report in this regard is incorrect.

Vapour Space Temperature Measurement

74. As explained above, LGPI’s practices during normal operation, which included daily measurements of the circulation loop inlet temperature and continuous monitoring of the temperature probe installed in Tank M6, in a region that was frequently mixed through additions and discharges of styrene were consistent with industry practice and sufficient.
75. Daily vapour space temperature measurements are not an effective means to detect the runaway auto-polymerization of styrene monomer since a majority of the temperature rise happens over a short duration that daily measurements would be unlikely to capture. Variation in the ambient weather conditions (temperature, wind, cloud cover, precipitation, etc.) also complicate the interpretation of daily vapour space temperature measurements. For example, a 2°C increase in vapour space temperature from one day to the next could be a normal occurrence due to simple day-to-day weather variability and not a cause for alarm.
76. As explained above, the physical evidence is consistent with a rapid event where the headspace of Tank M6 was not saturated with hot styrene vapours prior to the release. This evidence includes the lack of anybody smelling styrene either the day or night prior to the release, the suddenness of the rise in VOC

⁴⁸ Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 42.

concentration, and the transparency of the initial plume that indicates a large fraction of air in the headspace at the time of the release.⁴⁹ Since the event was sudden and the headspace had not been saturated with vapour from hot styrene, a daily vapour space measurement would have provided information that would have not allowed LGPI to detect, prevent, or mitigate the release. Therefore, the observation in the NGT Interim Report that Tank M6 does not have the provision of monitoring temperatures at vapour space is of no consequence.

Oxygen Measurement

77. Both oxygen and TBC are necessary to inhibit the polymerization of styrene monomer. Oxygen readily dissolves into styrene monomer. The vapour space above the liquid need only contain an oxygen concentration of 3% by volume to fulfil the oxygen requirement for inhibition. For comparison, air has an oxygen concentration of 20.9% by volume. In tank M6, air occupies the vapour space.
78. LGPI's practices during normal operation, which included an air headspace and frequent mixing through additions and discharges of styrene were consistent with industry practice and sufficient. There was no need to measure oxygen concentration in the headspace because the content of oxygen in ambient air far exceeds the requirement and is unlikely to be depleted.⁵⁰ There is no evidence that suggests a deficiency of oxygen caused or contributed to the styrene release. Therefore, there is no evidence to suggest such measurements would have provided any information that would have allowed LGPI to prevent or mitigate the release.
79. The NGT Interim Report wrongly concludes that prima facie, the vapour release happened because "[t]here is no monitoring system for dissolved oxygen in the vapour space which might have fall down below 6%."⁵¹
80. This statement is inaccurate for multiple reasons. This statement is technically flawed and demonstrates a lack of understanding due to its confusion of dissolved versus gaseous oxygen. A dissolved oxygen measurement is intended for measuring oxygen dissolved in the liquid. A dissolved oxygen measurement is not appropriate for measurement of oxygen concentration in a vapour space as stated in the NGT Interim Report.
81. Regardless, the tank was atmospheric and the ambient vapour space would have contained an oxygen concentration near 20.9% (the concentration in ambient air), which far exceeds the 6% requirement alleged by the NGT.

⁴⁹ See Paragraph 44 to 46 above.

⁵⁰ For example, Tank M6 contained approximately 1,900 MT of styrene. If the necessary oxygen content is about 8 ppm oxygen, that represents approximately 15 kg of oxygen within the liquid styrene. For comparison, the headspace contained approximately 1,000 m³ of 20.9% oxygen, which equates to about 300 kg of oxygen.

⁵¹ Interim Report of NGT Committee, 17 May 2020. p. 11

Oxygen measurements in a tank with an open connection to atmosphere were not required as the tank was openly connected with ambient air. Finally, the NGT Interim Report provides no evidence or analysis to suggest that oxygen depletion played any role in the styrene release.

82. Further, the claim that the dissolved oxygen concentration was too low is contradictory to the available evidence. The ambient headspace of the tank was full of air. Ambient air in equilibrium with styrene will yield a dissolved oxygen concentration of approximately 50 ppm or nearly 10 times the required amount to allow TBC to function. If oxygen is consumed inhibiting styrene, TBC would also be consumed.⁵² Therefore, the substantial quantity of available oxygen in the tank headspace and the lack of TBC depletion indicate that dissolved oxygen was not being depleted.

Refrigeration System

83. As explained above, to manage the styrene monomer during the lockdown without the ability to operate, LGPI developed a protocol, which included regular refrigeration in Tank M6. The refrigeration system (shown in Figure 3) was operated approximately 8 hours per day during the lockdown.⁵³

84. It has been claimed that, if the refrigeration system had been operated continuously, rather than one shift per day, the release may have been prevented. This is incorrect. To assess this claim and evaluate the temperature profile in the tank during the lockdown, a one-dimensional (1-D), transient thermal model of the styrene storage tanks was constructed and validated against the available data for Tanks M5 and M6.

85. The model was run considering two cases: one-shift per day operation and three-shift per day operation (*i.e.*, continuous operation). As shown in Figure 11, three-shift operation of the cooling system (dashed lines), compared to the one shift per day operation (continuous lines) during the lockdown, would have made no difference at the top of the tank and only marginal difference (about 1°C) at the bottom of the tank. Thus, additional operation of the refrigeration system would not have prevented the accident.

⁵² Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 15.

⁵³ The times when the refrigeration and circulation in Tank M6 was started and ceased each day is recorded in the logbooks maintained by the SMH operators known as the Patrol logsheet. For example, on 6 May 2020, the Patrol logsheet indicates the refrigeration and circulation was started at 8:30 AM and stopped at 4:00 PM.

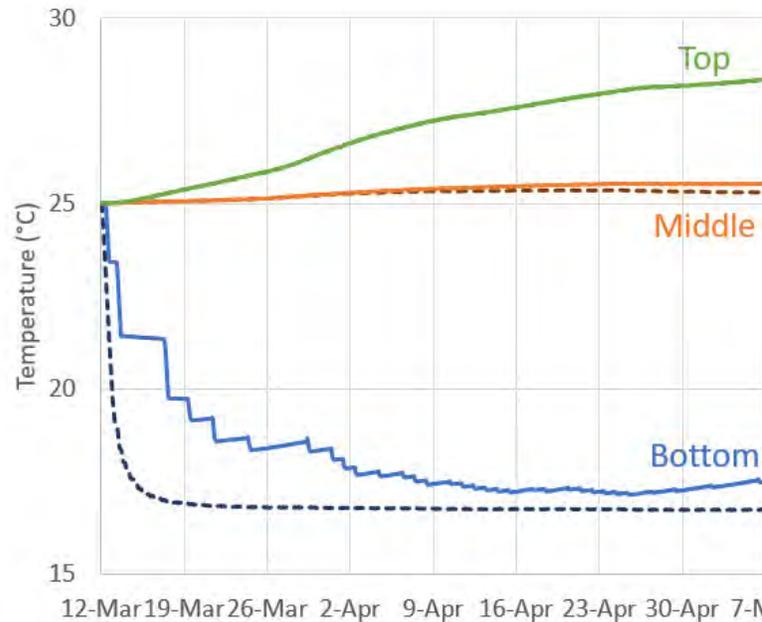


Figure 11. Calculated temperature profile in Tank M6 using the 1-D Transient Model for one shift per day (solid lines) and three shift per day operation (dashed lines). The operation strategy for the chiller (one shift vs three shift) does not impact the temperatures higher in the tank.⁵⁴

86. Thus, the NGT Interim Report wrongly concludes that prima facie, the vapour release happened because *“Refrigeration system is not being operated for 24 hours.”*⁵⁵

87. In the final report, the NGT also states *“There is no interlock system arrangement between the temperature and refrigeration system.”*⁵⁶

88. We agree that no interlock exists between the bottom temperature sensor and the refrigeration and circulation system. However, because the gas release occurred before an increase in the measured bottom temperature, an interlock between the refrigeration system and tank temperature would not have prevented the release.

TBC Concentration

89. As explained above, to manage the styrene monomer during the lockdown without the ability to operate, LGPI developed a protocol, which included monitoring of the TBC content.⁵⁷

⁵⁴ Bottom, middle and top refers to 1.1 meters, 4.2 meters, and 7.9 meters, respectively.

⁵⁵ Interim Report of NGT Committee, 17 May 2020. p. 11

⁵⁶ Final Report of NGT Committee, 28 May 2020. p. 15

⁵⁷ Lockdown SOP dated 1 April 2020

90. At the start of the lockdown, the TBC content was measured to be 20 ppm in Tank M6 on both 23 and 24 March.⁵⁸
91. To mitigate the auto-polymerization hazard of the styrene monomer remaining in the shore tanks (which lacked insulation and refrigeration), LGPI also added approximately 20 kg of its approximately 45 kg stock of TBC to the shore tanks on 1 April (10 kg per tank). On 16 April and again on 20 April, LGPI attempted to order more TBC but were unable to obtain it due to the restrictions of the lockdown. After the 21 April delivery of styrene, LGPI added its remaining TBC supply to the shore tanks.⁵⁹
92. As expected, due to normal depletion of the TBC, the TBC in tank M6 gradually decreased from around 20 ppm to 15 ppm during the lockdown. Specifically, the TBC concentration was measured to be 15 ppm at both the top and bottom of Tank M6 on 25 April.⁶⁰ Based on the measured TBC concentration (15 ppm) at the top of the tank, the inhibitor at the top of the tank would be expected to remain at recommended levels (10-15 ppm) until at least 30 May.⁶¹
93. LGPI's practices (both during lockdown and normal operation), which included regular measurements of the TBC concentration, were consistent with industry practice and sufficient.⁶² As the TBC concentration remained within the recommended range for the entire lockdown, additional measurements would not have provided additional guidance or assisted in mitigating or preventing the release.
94. A quantitative analysis was also performed to evaluate the expected rate of depletion of TBC based on temperatures at both the bottom and top of the tank.⁶³ Modelling results were compared to the available data (see Figure 12) to estimate the original TBC concentration and predict the time when the TBC concentration would have been expected to reach dangerous levels.

⁵⁸ See Figure 2.

⁵⁹ Based on facts / data provided by LGPI.

⁶⁰ See Figure 2.

⁶¹ Based on the estimated TBC depletion rates at 30°C published in Table 4 of Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 15.

⁶² Safe Handling and Storage of Styrene Monomer, Chevron Phillips Chemical Company, L.P., September 2010, p. 16; Safe Handling and Storage of Styrene Monomer, Americas Styrenics LLC, November 2016, p. 14; Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 13.

⁶³ The chemical kinetics for the TBC depletion were based on Table 4 of the Styrene Producers Association Styrene Safe Handling Guide using the Arrhenius kinetic equation. It was assumed the tank started with a uniform TBC concentration. Tank temperatures calculated in Figure 11 were used.



Figure 12. Model prediction of TBC concentration over time versus measured data.

95. The results show that the bottom TBC depletion data agrees with the available data. The measured value of 15 ppm at the top of Tank M6 on 25 April is within 2 ppm of the model prediction.
96. The model is extrapolated to future times in Figure 13 to determine when the TBC concentration would have passed various thresholds. It is estimated the TBC concentration would have reached 10 ppm, which is the minimum recommended value, around 20 May. It likely would not have reached 4 ppm, the threshold when polymerization is likely to occur, until July.

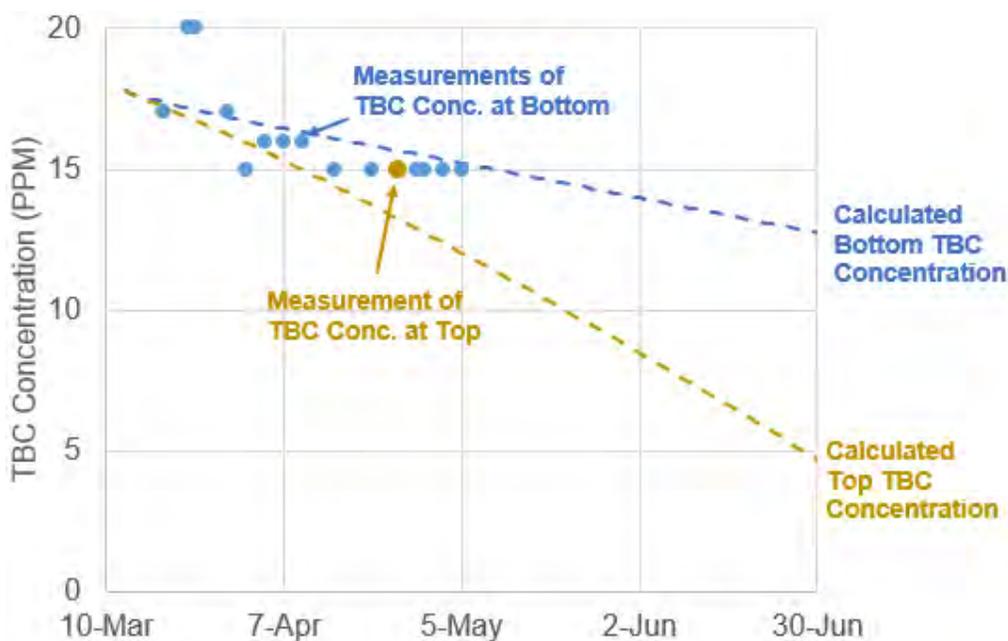


Figure 13. Model prediction of TBC concentration at longer times.

97. Therefore, based on the typical depletion rates of TBC and the temperatures in Tank M6, the TBC would not have been expected to have reached critically depleted levels until many weeks after the styrene release occurred. This is consistent with the measured data.
98. The NGT Interim Report wrongly concludes that prima facie, the vapour release happened due to *“Insufficient TBC concentration in styrene due to unavailability of TBC in the plant.”*⁶⁴ Further, in the NGT Final Report, the NGT alleges that *“Also, no TBC was topped up in the affected tank M6 since April 1 since there was no stock at site and the tested TBC level of the contents was apparently in range. Clearly, it can be realized that the TBC level is not a good indicator of safety margins; the polymer content is a better measure for an early alert.”*⁶⁵
99. These statements are inaccurate and misleading. The unavailability of TBC had no role in the TBC concentration in the tank because there were no indications that additional TBC was warranted and, therefore, even had TBC been present, there was no reason for LGPI to have added it. Further, the NGT reports provide no comment or analysis on how much should have been added or how much would have been necessary to prevent the release.

⁶⁴ Interim Report of NGT Committee, 17 May 2020. p. 11

⁶⁵ Final Report of NGT Committee, 28 May 2020. p. 16

Polymer Concentration Measurement

100. In their Final Report, the NGT assert that the “[r]oot cause analysis showed that the problem possibly began on April 20, 2020 when the polymer concentration in Tank M6, which was idled at full capacity since March 25 post-lockdown.”⁶⁶
101. Elevated polymer concentrations were first observed at the top of Tank M6 on April 25th. Elevated concentrations were obtained at the bottom of Tank M6 on April 28th. The concentrations stabilized at the bottom between May 2nd and May 5th.⁶⁷ The sudden increase and stabilization of polymer level was not abnormal and was consistent with prior occurrences and believed to be due to polymer deposits in Tank M6 contacting the styrene monomer due to the receipt of 73 MT on 21 April. The dissolution of polymer deposits into the monomer is a well-established phenomenon in the styrene industry. For example, an excerpt of the Styrene Producers Association Safe Handling Guide is shown in Figure 14.

Q7: Does a high polymer level always mean the bulk of the product is polymerising?

No.

- Bulk polymerisation can be recognized by a gradual increase of the polymer levels, a gradual depletion of TBC levels and a slight increase in temperature.
- Condensing styrene vapour against tank roof or internals does not contain inhibitor and can form polymer stalactites. These can break off and dissolve in the bulk. This can be recognised as a sudden increase in polymer levels and constant TBC levels.

Figure 14. Excerpt from Styrene Producers Association Safe Handling Guide (pages 41-42).⁶⁸

102. The polymer level increase was sudden, not gradual, and there was no corresponding depletion of TBC or rise in temperature as would be expected if auto-polymerization were occurring. Further, no temperature rise or safety concern had been observed during prior experiences with elevated polymer concentrations. Thus, the NGT Committee’s uncertain statement that polymer levels measured in late April in Tank M6 “possibly” indicated the start of a problem are not consistent with the physical evidence or industry guidance. If the NGT Committee is suggesting a hotspot near the top of the tank led to the observed polymer values, they have failed to explain or demonstrate why the

⁶⁶ Final Report of NGT Committee, 28 May 2020. p. 15

⁶⁷ See Figure 2

⁶⁸ Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, pp. 41-42.

rise in polymer values was sudden and then stable rather than gradually increasing.

Progression of the Auto-Polymerization

103. In their Final Report, the NGT state that progression of the event included a “*slow but steady formation and growth of a hotspot within the tank where an exothermic (heat-generating) reaction of polymerization started. By early morning of May 7, the hotspot probably reached critical mass.*”⁶⁹
104. In their Interim Report, the NGT state that “a[s] soon as a temperature elevates to above 65°C it takes about just 15-20 minutes before a complete runaway.”⁷⁰ However, the PlasticsEurope Styrene Handling Guide that they reference indicates that the time until water boiling would be much greater than 20 minutes. The PlasticsEurope guide provides a figure to evaluate the time until water boiling.⁷¹ PlasticsEurope states, for example, “[t]he TWB (Time to Water Boiling) graph in Figure 7 can be used to make an evacuation decision: e.g. if it is 85 °C, the storage tank may rupture within 100 minutes.”⁷² An annotated version of that graph that highlights the time until boiling for a tank at 65°C is provided in Figure 15. As indicated by the annotations, it would require at least 800 minutes (more than 13 hours) to boil.

⁶⁹ Final Report of NGT Committee, 28 May 2020. p. 15

⁷⁰ Interim Report of NGT Committee, 17 May 2020. p. 8

⁷¹ Note, the graph calculates the time until to water boiling in a styrene tank, which would occur in a slightly sooner period than styrene boiling. Therefore, the time until styrene boiling would be slightly greater than the value represented in the plot.

⁷² Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 42.

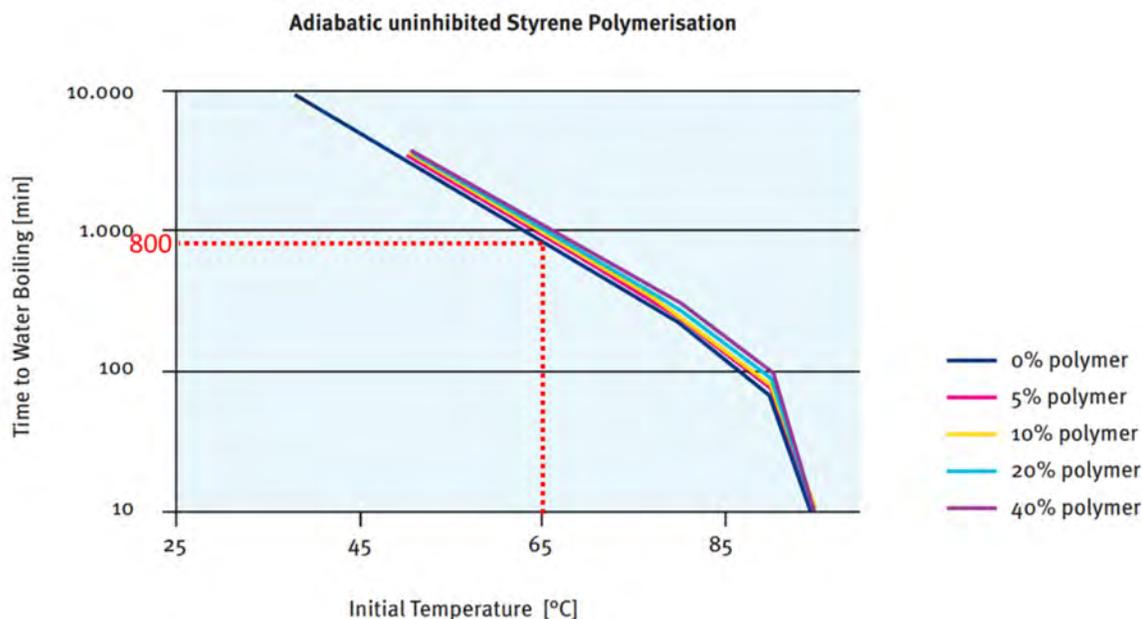


Figure 15. Reproduction of Figure 7 of the PlasticsEurope Styrene Handling Guide with annotations indicating the time to water boiling at 65°C.⁷³

105. As described in the Styrene Vapour Release section, the release occurred suddenly without any indications in the available data. The release did not slowly develop over days as would be expected from a slow progression. The low optical density of the initial plume as captured in CCTV images indicates the tank headspace had not significantly heated and that the contents of the headspace within the tank was primarily air. This is inconsistent with a “slow but steady” formation of a hotspot. If the heating were slow, the tank headspace would have been saturated with warm styrene vapours and the initial styrene concentration of the plume would have been greater.
106. The NGT further asserts in their Interim Report that “[i]n the present incident, absence of TBC inhibitor, improper refrigeration and stagnant conditions of styrene monomer...for about 45 days would have led to free radical polymerization of styrene molecules.”⁷⁴
107. This assertion is incorrect for several reasons. TBC was consistently observed to be present in the tank at industry recommended levels. There is no evidence of significant TBC depletion anywhere in the tank. Further, they provide no analysis to support their conclusion that the conditions were sufficient to cause auto-polymerization in 45 days. Published data from industry guidelines and the quantitative analyses provided in this report indicate that the auto-

⁷³ Styrene Monomer: Safe Handling Guide, Styrene Producers Association, PlasticsEurope, July 2018, p. 43.

⁷⁴ Interim Report of NGT Committee, 17 May 2020. p. 9

polymerization would have required an additional two months of storage to occur.

Gas Detection and Alarm System

108. In their Final Report, the NGT incorrectly assert “[a]s per CCTV record, the emission started at about 02:42 hrs from M6 tank having 1830 tonnes of styrene. No alarm generated when vapour leakage occurred and auto sensor of styrene is failed to detect the conc. in ppm.”⁷⁵
109. The allegation that the automated alarm system failed to notify the operators of the emergency is not consistent with the available data. The level sensor data indicates an increase in pressure two minutes prior to when the CCTV records the release.⁷⁶ Similarly, the gas detectors also triggered the alarm within one minute of when emissions are visible on the CCTV footage. Therefore, the LGPI system did function appropriately and did rapidly detect the release and alert the operators.

Pressure Relief of Tank M6

110. In their Final Report, the NGT incorrectly assert that “[h]ad the safety valve failed, the whole tank would have been exploded and still bigger catastrophe would have been happened.”⁷⁷
111. This statement is not accurate or applicable to the design of Tank M6, an atmospheric tank. Tank M6 is not a pressure vessel and does not have a safety valve. Instead, M6 was designed to openly communicate with the exterior atmosphere through an 8-inch diameter opening, the dip hatch.⁷⁸ Further, the tank was designed such that an internal overpressure would lead to a separation first at the weld joint between the roof and shell, in accordance with Indian Standard (IS) 803 First Revision (1976, reaffirmed many times, most recently in 2017).⁷⁹ This separation occurred during the release per design and prevented significant pressure build up and thus prevented a more damaging failure.
112. The separation of the weld seam is not unexpected and is a common design feature of atmospheric tanks. The tank is not intended to be a pressure vessel, and thus the seams are not designed to handle any significant overpressure. To the contrary, the seams are specifically designed to open in a benign manner at a low overpressure. Indian Standard IS 803 allows for frangibility of

⁷⁵ Final Report of NGT Committee, 28 May 2020. p. 15

⁷⁶ Based on the 12 minute offset between the DCS system and CCTV system. The NGT Report does not appear to correct for this offset in their analysis.

⁷⁷ Final Report of NGT Committee, 28 May 2020. p. 14

⁷⁸ M6 Tank Drawing

⁷⁹ IS 803-1976 Vertical Cylindrical Storage Tanks, Section 6.4.2.5. (relevant extracts enclosed herewith as **Appendix 15**)

the weld joint between the roof and shell. Section 6.4.2.5 states: “[i]f the continuous fillet weld between the roof plates at the top angle attachment does not exceed 5 mm and the slope of the roof at the top angle attachment does not exceed 1 in 6, the joint may be considered to be frangible.... Where the weld size exceeds 5 mm or where the slope of the roof at the top-angle attachment is greater and 1 in 6, emergency venting devices in accordance with Appendix C shall be provided by the purchaser.”⁸⁰

113. If the Tank M6 did not have this frangible joint design feature, the tank shell could have failed due to the internal pressurization, leading to a much more sudden release of a much larger amount of styrene. The separation at the roof seam is therefore an expected, favourable result, as it prevents a more catastrophic failure mode.
114. Additional assertions made in the NGT Final Report about “blockages in the tank”⁸¹ and the tank being a “closed container”⁸² are inaccurate and demonstrate a lack of understanding of the mechanics of Tank M6.

Sprinkler Systems of Tank M6

115. The NGT in their Final Report state that “*There is no external water spray arrangement over the storage tank for exceeding ambient air temperature and also any unmanned hose arrangement.*”⁸³
116. While the sprinklers were not automated to respond to a styrene vapour leak, they were designed to activate at a temperature of 68°C, which would occur in the event of a fire or explosion.⁸⁴ This was an appropriate design based on industry experience with styrene accidents. The sprinklers were also designed to be able to be activated at a valve outside the bund wall, which was opened by LGPI personnel in response to the release.

Quantity of Styrene Released

117. The NGT alleges in their Final Report that “[a]n estimated 800 tons (8 lakh kg) of styrene escaped into the surroundings in the incident.”⁸⁵ No calculation or explanation is provided to justify such a value.
118. To assess the quantity of styrene released to the surroundings the following should be included:

⁸⁰ For Tank M6, the angle of the roof was 1 in 12 (a peak of 0.75 m above the horizontal over a radius of 9 m) and the weld size did not exceed 5 mm. Thus, M6 met the criteria for a “frangible” roof connection according to IS 803.

⁸¹ Final Report of NGT Committee, 28 May 2020. p. 14

⁸² Final Report of NGT Committee, 28 May 2020. p. 14

⁸³ Final Report of NGT Committee, 28 May 2020. p. 15

⁸⁴ See paragraph 58.

⁸⁵ Final Report of NGT Committee, 28 May 2020. p. 15

- a. Measurement of the remaining polymerized styrene in the tank including material resting on the bottom of the tank and material adhered to elevated surfaces
 - b. The 95 MT that were transferred to other tanks within LGPI
 - c. Estimation of material that was caught within the bund wall.
 - d. Estimation of material that was caught within the LGPI border wall.
119. Tank M6 and the surrounding area is not currently available for inspection. Therefore, the above cannot be completed at this time.

Experience of LGPI

120. In their Final Report, the NGT assert that “[w]ith the experience world over of Styrene, it takes considerable amount of idle time to have polymerization inside tank if effective inhibition and chilling is maintained. The unit failed to assess this situation due lack in handling experience by trained man-power.”⁸⁶
121. LGPI did monitor the inhibitor concentration, which remained at an effective level according to every measurement performed.⁸⁷ LGPI also effectively operated the chiller to maintain bottom temperatures below 20°C.⁸⁸ LGPI’s interpretation of the available data was reasonable and there were no indications of an imminent vapour release prior to the accident.
122. We agree that the exceptionally long duration of idle time played a role in the styrene release that occurred but disagree with the characterization of LGPI experience. LGPI has extensive experience handling styrene monomer and preventing polymerization. This is evidenced by decades of successful operation. The sudden, forced, long-duration storage of styrene monomer in a tank that was never intended to be used without frequent deliveries and outflows was unprecedented.

Conclusions

123. Based on the available information, the direct event that initiated the release cannot be determined. None of the available data indicated that auto-polymerization was occurring or imminent prior to the release. The auto-polymerization that led to the styrene vapour release only occurred due to the unprecedented and prolonged stagnation in Tank M6. The root cause of the prolonged stagnation was the forced sudden and prolonged shutdown of plant operation due to the restrictions of the Covid-19 lockdown.
124. Many of the conclusions of the NGT reports are provided without any quantitative analysis of the available data. When we performed quantitative

⁸⁶ Final Report of NGT Committee, 28 May 2020. p. 16

⁸⁷ See Figure 2

⁸⁸ See Figure 1

analyses to evaluate these claims, the results contradicted the findings of the NGT reports. Specifically, the analyses contradict the NGT's assertions that additional temperature sensors, oxygen measurements, or 24-hr operation of the refrigeration system would have prevented the release. Further, the NGT's description of the progression of the event, the significance of the polymer concentration data, and requirements for styrene storage are contradicted by published industry guidance.

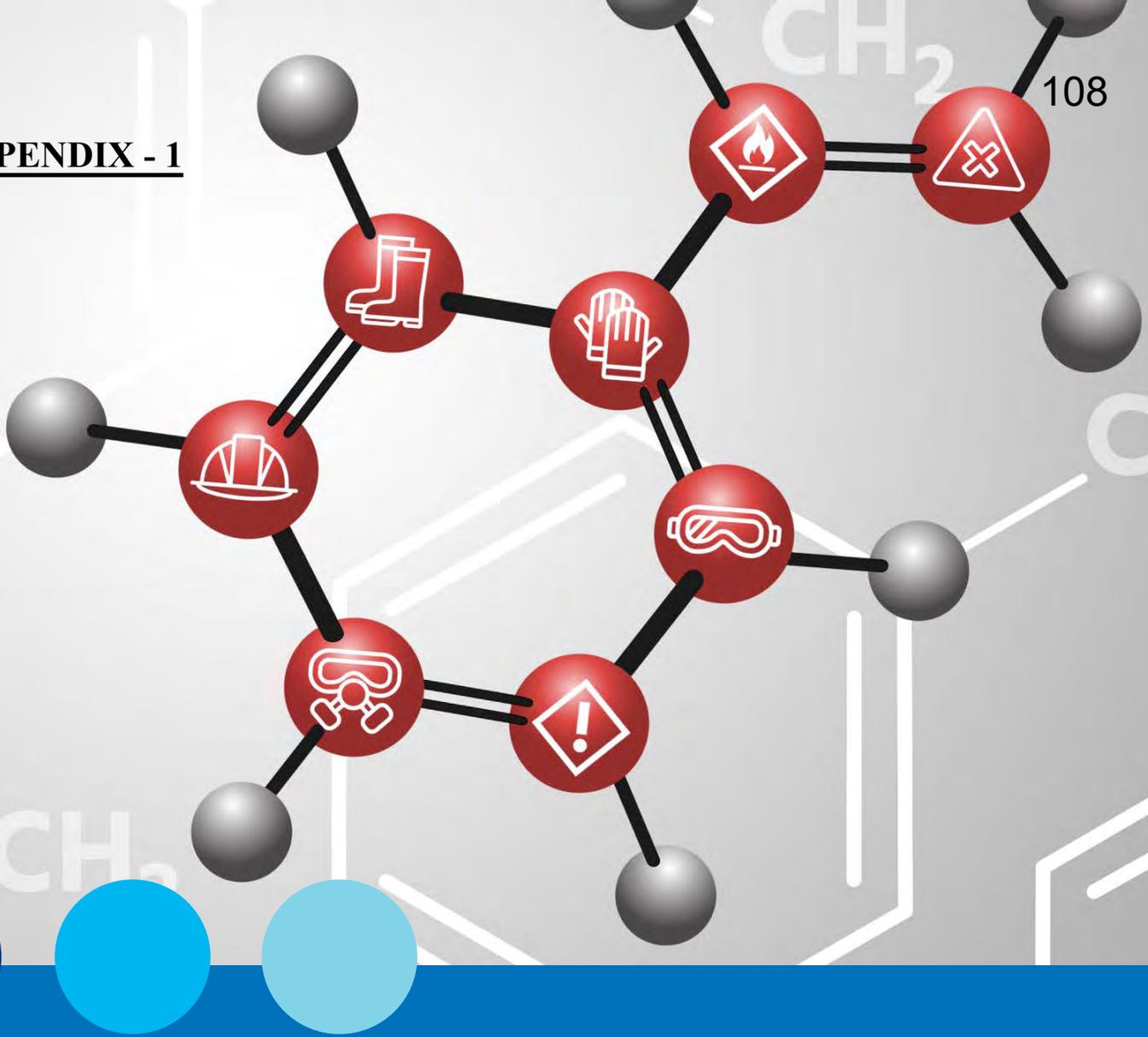


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7 November 2020



Styrene Monomer: Safe Handling Guide

July 2018

Styrene Association (SPA)

The Styrene Producers Association (SPA) is a Sector Group of PlasticsEurope's Styrenics Chain, which gathers representatives from the companies mentioned below.

PlasticsEurope would also like to thank these companies for their valuable contributions and peer review of this document:

BASF SE

INEOS Styrolution Europe GMBH

LyondellBasell

Repsol Química S.A.

Shell Chemicals Europe B.V.

Total Petrochemicals & Refining

Trinseo Europe GmbH

Versalis spa

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1. Introduction and purpose

The purpose of this document is to review the environmental, health and safety aspects of styrene, i.e. how to handle, store and distribute the material according to current industry standards and guidelines. The Styrene Producers Association (SPA), a Sector Group of PlasticsEurope/Styrenics Chain, encourages customers and potential users of styrene to review their applications from the standpoint of human health and environmental quality.

A key document in this respect is the Safety Data Sheet (SDS) provided by your supplier. The SDS is an invaluable source of health and safety information, and is available in many languages. To help ensure that the product is not used in ways for which it is not intended or tested, producers will assist customers in dealing with ecological and product safety considerations. For information on specific applications of styrene, users are urged to contact the customer service centre of their suppliers.

SPA considers the volume and the distribution pattern of styrene as a commodity chemical to warrant specific emphasis on the application of Responsible Care¹ principles in the distribution of styrene. The transfer of styrene by road, rail, sea or inland water is subject to local and international regulations and agreements that must be observed by all parties involved. National laws may differ from international regulations and may be stricter than the distribution guidelines outlined in this brochure.

The transfer of styrene in bulk road tankers, rail tank cars, seagoing vessels, barges and tank containers is taken into account covering all aspects of the transport activity from the loading to the delivery point. Reference to existing regulatory controls and measures is made for clarification purposes only. SPA members do not ship styrene in drums, hence specific distribution risk management requirements for drums are not discussed herein. However, individual companies will offer guidance to their customers in cases of styrene delivery in drums.

SPA recommends that the Styrene Monomer: Safe Handling Guide is adopted by all parties involved in the transfer of styrene, including commercial transaction partners for product swaps, toll or trade agreements along with customer collection arrangements. The latter arrangements should adhere to the same distribution safety principles as if conducted by the manufacturing supplier.

DEFINITIONS

Inhibitor	Chemical that is added to another chemical to prevent an unwanted reaction (e.g. polymerisation).
Retarder	Chemical that is added to another chemical to slow down an unwanted reaction (e.g. polymerisation)
Short Stop	A free radical scavenger that can be added to a polymerizing system to temporarily halt the polymerization. When the short stop is consumed the polymerization will continue.
Runaway	Self-accelerating chemical reaction (e.g. polymerisation). During a runaway the temperature will rapidly increase.

¹ See Appendix 1

2.3. Manufacturing and Use

The conventional method for producing styrene involves two steps: the alkylation of benzene with ethylene to produce ethylbenzene, followed by dehydrogenation of the ethylbenzene to produce styrene (refer to Figure 2). Over the almost fifty years of practicing the conventional two-step process, refinements have constantly been made to improve conversion and selectivity of ethylbenzene and finally of styrene along with design changes to conserve and utilize the energy, in particular from the exothermic alkylation step. The traditional aluminium chloride catalyst used in this alkylation is now (2018) almost completely replaced by zeolite catalyst technology. Currently, the predominant route for the commercial production of styrene is by dehydrogenation of ethylbenzene in the presence of steam over a catalyst (iron oxide) in fixed bed adiabatic or, in some cases, tubular isothermal reactors. Another route involves co-production of styrene and propylene oxide via hydroperoxidation of ethylbenzene. Limited scale extraction from steam cracker pyrolysis gasoline is also practised.

The specification and analytical methods for styrene monomer have changed through the years. The majority of manufacturers have defined their specifications according to the standard D2827 “Standard Specification for Styrene Monomer” of the American Society for Testing and Materials (ASTM). Key parameters of rev. 13 of D2827 specification are:

- a minimum purity of 99.8 wt. %
- a maximum colour of 15 on the Platinum-Cobalt (Pt-Co) scale
- inhibitor (TBC) concentration between 10-15 ppm
- Polymer content of maximum 10ppm

The impurities and their concentrations depend upon the manufacturing route employed, along with plant performance characteristics. The inhibitor content specified in the standard is 10-15 ppm TBC (4-tert-butylcatechol), to meet minimum shipping

requirements. Higher levels may be defined in the customer specification to increase stabilization (shelf life), depending on the expected transport/storage duration and temperature.

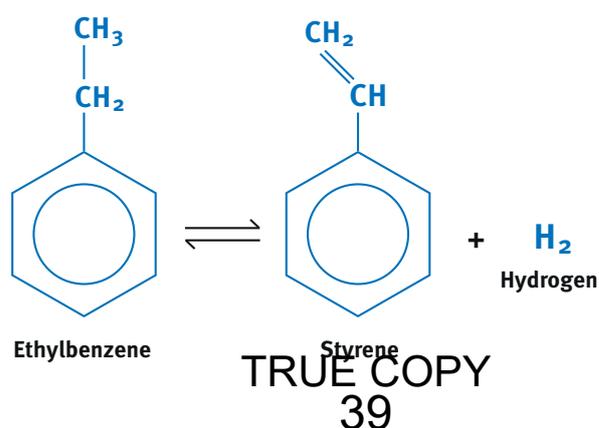
Styrene is predominately used in the manufacture of plastics and synthetic rubber, such as polystyrene, EPS, engineering plastics like ABS, and styrene-butadiene rubber. It's one of the most versatile and widely-used monomer building blocks with ability to be polymerised by free radical, cationic, anionic, thermal, group transfer, and redox techniques. Furthermore, it copolymerises readily with other vinyl-based monomers, such as acrylonitrile, butadiene, acrylates, and maleic anhydride. Polymers made with styrene ultimately find end-uses in packaging, medical, appliance, automotive, electronics, construction, and others.

2.4. Inhibition of Styrene (Chemistry, Mechanism and Levels)

2.4.1. Safety

Styrene is a reactive monomer, undergoing many reactions of an unsaturated compound (such as addition) and of an aromatic compound (such as substitution). Polymerisation generally takes place by free-radical reactions initiated thermally or catalytically. Polymer formation occurs slowly even at ambient temperatures and becomes rapid at elevated temperatures. To maintain the monomer content for quality as well as safety reasons, the polymerisation reaction is retarded or inhibited by phenolic inhibitors. The most commonly used inhibitor is tertiary-butyl catechol (4-tert-butylcatechol (TBC) or p-tert-butyl catechol; CAS RN 98-29-3; EC No.: 202-653-9). The polymerisation reaction is exothermic and if contained may become violent. If the heat is not removed, the bulk styrene temperature may rise to a level at which polymerisation is self-sustaining and very rapid, evolving the release of large quantities of heat together with volumetric expansion.

Figure 2: Dehydrogenation of Ethylbenzene to Styrene



An inhibitor must be maintained at certain minimum levels to prevent polymer formation. The presence of dissolved oxygen is required for the inhibitor to function properly, therefore styrene needs to be stored under air or inert gas with sufficient oxygen levels.

Storing and transporting styrene is better at low temperatures. This slows down the polymerisation reaction. In addition to using TBC, temperature control and proper selection of storage and transport environment should ensure shelf life with the necessary quality specifications. See appendix 2 for more detail.

Styrene should never be handled under an oxygen-free atmosphere. Air is preferable to support the inhibitor mechanism. If ambient temperatures are above flash point, it might be desirable to use a nitrogen/oxygen gas mixture to avoid flammability. However, the atmosphere above styrene monomer should contain a minimum oxygen level to maintain inhibitor effectiveness.

A study on the inhibition chemistry confirmed that oxygen is consumed as part of free radical scavenging mechanism. Thus, the atmosphere above styrene

monomer in a closed system should be periodically replenished with air or a nitrogen/oxygen gas mixture. Based on the experiences of SPA members, a minimum oxygen level of 3 vol% in the vapour phase is regarded as being sufficient for inhibition of the liquid phase, provided that all other parameters (temperature, polymer content, TBC content) are within recommended ranges. More than 8 vol% of oxygen in the vapour phase can lead to a flammable mixture (see figure 3). The recommended optimum oxygen level is 5% volume. The solubility of gases in styrene is shown in table 2.

It should be noted that in climate zones and in seasons with significant temperature differences between night and day, the styrene vapours evolved in the headspace at higher temperatures will condense on roofs, walls and internal fittings of storage tanks when it cools off. The phenolic inhibitors have high boiling points and stay in the liquid phase, resulting in the condensed styrene vapours containing no inhibitor. Precautions must be taken to prevent polymer build-up on surfaces above the liquid level of tanks and containers that could result in the plugging of pressure-relief valves.

Figure 3: Flammability Diagram for “Styrene/Oxygen/Nitrogen”

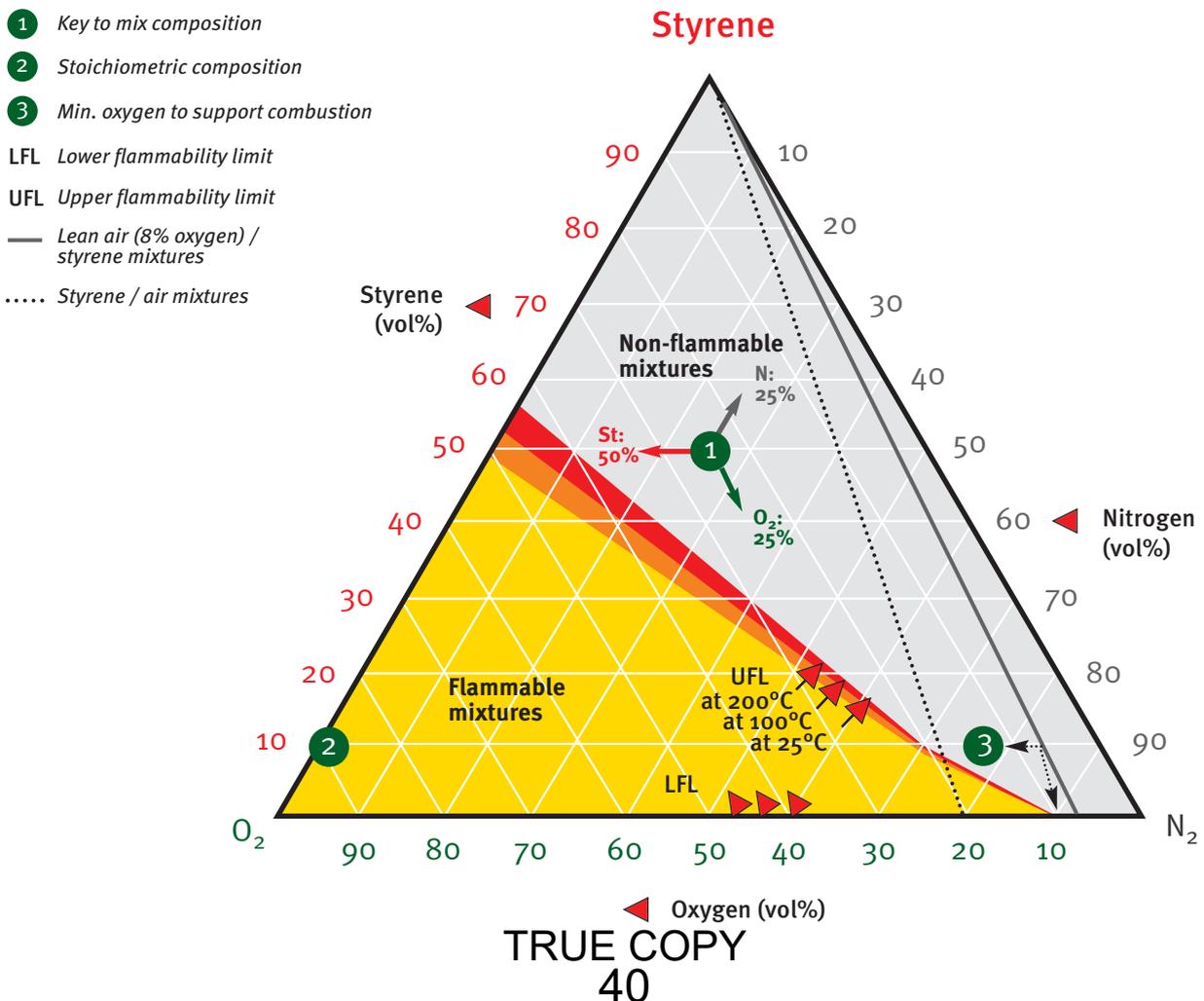


Table 2: Solubility of Gases in Styrene at 25°C

Gas	CC Gas/CC Styrene	Ppme by wt.
Oxygen	0.4	581
Nitrogen	0.08	102
Air	0.15	198
O ₂ from air*	0.032	50

*Amount of oxygen when saturated with air

In warm climates, consideration can be given to applying a coating on the internal surfaces of tanks, thereby preventing discolouration of the styrene from oxidised iron and minimizing polymer build-up in the headspace. US patent 4,161,554 describes a coating system employing TBC, which upon one single application is expected to last for several years.

It is recommended that the maintenance and inspection schedule for storage of styrene be followed as indicated in Table 3, which includes auxiliaries such as vapour return lines and safety valves.

Table 3: Schedule for Styrene Storage Testing

Checkpoint	Interval	Remarks
Inhibitor Analysis	1 time weekly	If below 15 °C
	2 – 3 times weekly	If between 15 and 25 °C
	Daily	If above 25 °C
Polymer Analysis	1 time weekly	If below 15 °C
	2 – 3 times weekly	If between 15 and 25 °C
	Daily	If above 25 °C
Monomer Temperature	Daily	
Monomer Vapour Temperature	Daily	
Product Turnover		
Date of last filling	Running log	
Volume before filling	Running log	
Volume after filling	Running log	

2.4.2. Inhibition Chemistry

When styrene monomer (M) is exposed to light and/or heat, it forms radicals (see Figure 5). These styrene radicals (R*) react either with oxygen to form peroxide radicals or with styrene to form polymer chains. In the presence of sufficient oxygen (at least 10-15 ppm), the peroxide formation is significant because this reaction (r1) is much faster compared to the polymer formation with styrene (r2). In the subsequent step, if inhibitor (TBC) is present, the peroxide radicals are scavenged via quinone formation (r3); whereas, if no inhibitor is present, the peroxide radicals react with styrene to form peroxide chains (r4). Oxygen works as the polymerisation inhibitor, while TBC controls its efficient use. In the absence of TBC, the peroxy-radicals continue to react with the monomer and oxygen molecules until the

oxygen is completely depleted. The poly(peroxides) are soluble in styrene and will not concentrate. Hazardous situations may occur during distillation of styrene contaminated with unstable poly(peroxides), which may trigger a runaway reaction since with temperature increase a significant number of radicals may be formed.

Note: Considering the minimum oxygen concentration to support combustion (see Figure 3), the IMO-related Safety Of Life At Sea (SOLAS) Convention has defined an atmosphere with < 8vol-% oxygen as inert gas for styrene.

For the proper functioning of TBC, oxygen in vapour phase should be minimum 3 vol-%, which is equivalent to 8 ppm of dissolved oxygen in liquid phase (Figure 4).

Figure 4: Equilibrium of oxygen concentration in gas phase and liquid styrene at 25°C and 1bar

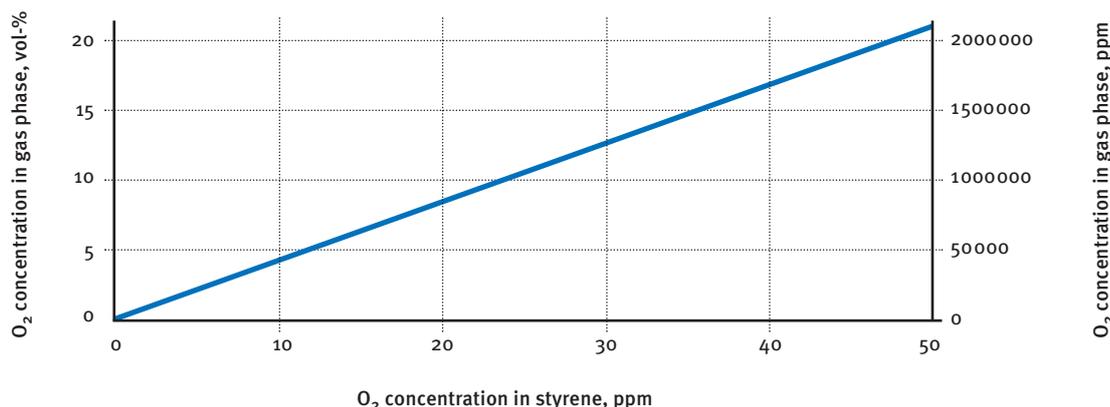
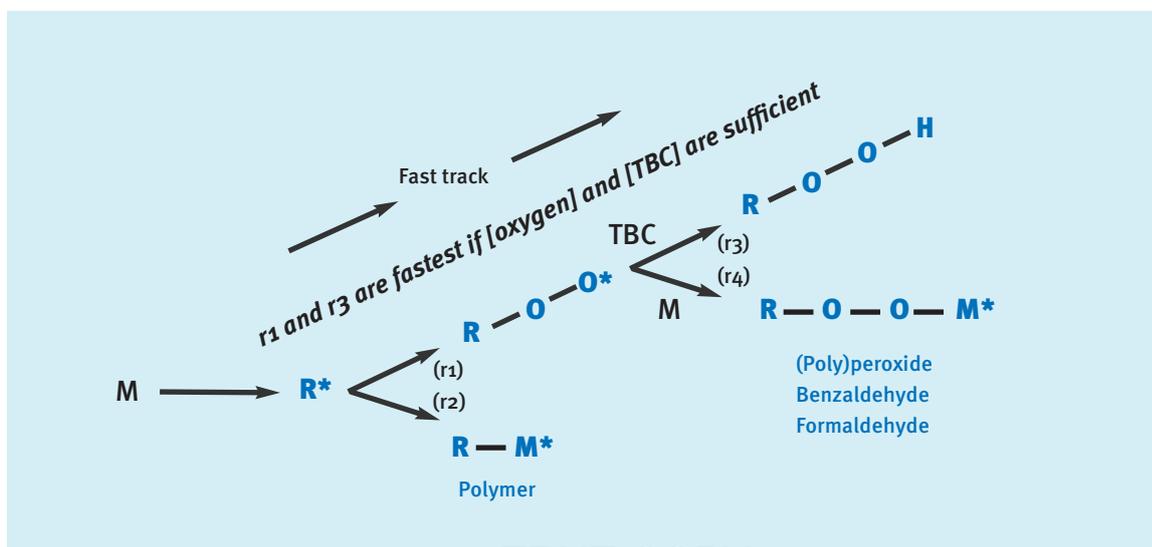


Figure 5: Inhibition Mechanism



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2.4.3. Standard Inhibitor Levels

The required inhibitor (TBC) concentration to prevent polymerisation depends on temperature and residence time in the tank.

The recommended practice is to maintain the inhibitor (TBC) levels between 10-15 ppm, but higher inhibitor levels may be required depending on the storage conditions, process or specific user requirements. Typical protection in days for styrene, when inhibitor levels are at the recommended levels in the presence of air, are shown in Table 4.

Styrene users are advised to have a TBC concentrate/solution on-site to restore the TBC below the recommended concentration.

The depletion of oxygen in styrene is not only dependent on the temperature, but also on the TBC level added. At low TBC levels, oxygen depletion is rapid and the inhibition system will quickly become ineffective. Lower oxygen levels will lower the shelf life at the moment it comes below 3 vol-%.

2.4.4. Short Stop

If polymerisation has started and the temperature in the tank or transport is rising, it is possible to reduce the polymerisation rate significantly by adding a free radical scavenger (Short Stop). After adding Short Stop, the styrene has to be re-processed or discarded. Inhibitors suitable for Short Stop are **DEHA** (a free radical scavenger Diethylhydroxylamine CAS Registry Number: 3710-84-7 CA Index Name: Ethanamine, N-ethyl-N-hydroxy-), **4-Hydroxy-TEMPO** (a stable free radical, CAS Registry Number: 2226-96-2 CA Index Name: 1-Piperidinyloxy, 4-hydroxy-2,2,6,6-tetramethyl-) and **4-Oxo-TEMPO** (a stable free radical, CAS Registry Number: 220-778-7, CA Index Name: 2,2,6,6-Tetramethyl-4-oxopiperidinoxy).

Other free radical scavengers can also be suitable.

Table 4: TBC Depletion in Styrene (if stored under air)

Temperature °C t	Depletion Days/1 ppm	TBC Content		Shelf Life Assured days
		[initial] ppm	[end]	
25	11	15	10	55
30	7	15	10	35
40	1.5	15	10	7

Note: Oxygen inhibits polymer formation, TBC controls the oxygen depletion rate.

2.5. Environmental Effects

EU Risk Assessments have concluded that styrene is not bio-accumulative, meets the criteria for ready biodegradation and thus does not require classification for environmental effects. See Section 2.7- European Regulatory Environment.

Persistence of styrene in the environment is very limited because of its volatility from soils and surface waters, its rapid destruction in air and its biodegradation in soils, and surface and ground waters.

Styrene is acutely toxic to aquatic organisms. Due to its high depletion rate from water the exposure rate may be very low.

More details on styrene's environmental effects can be found in Section 4 "Environmental Aspects".

2.6. Transport Classification (Europe)

For current Transport Classifications, please refer to the following sources:

Rail transport: Convention concerning International Carriage by Rail (COTIF) Appendix C – Regulations concerning the International Carriage of Dangerous Goods by Rail (RID, 2017)²

Inland waterways: European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN)³

Bulk marine transport: International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code).

Marine transport of packaged goods: International Maritime Dangerous Goods Code (IMDG Code, 2016).

Road transport: The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR 2017)⁴

Air transport: International Civil Aviation Organisation Technical Instructions (ICAO TI 2017)

² http://otif.org/fileadmin/new/3-Reference-Text/3B-RID/RID_2017_E.pdf

³ https://www.unece.org/trans/danger/publi/adn/adn2017/adr2017_e.pdf

⁴ http://www.unece.org/fileadmin/DAM/trans/danger/publi/adr/adr2017/ADR2017e_web.pdf

Appendix 2.

Styrene polymerisation in storage

The following are a series of Questions and Answers on the subject of styrene polymerisation. The purpose of these Q & As is to facilitate the decision making process in the event of a styrene polymerisation situation.

Q1: What parameters should be measured if polymer content is rising?

- Polymer content (< 10 ppm, depending on product spec.)
- Temperature (\ll 2-3°C/day). If the temperature rises 1°C/day, it is advised to be alert and keep monitoring the temperature actively. Re-circulation could stop the temperature rise. A 2-3°C/day temperature increase is a typical indication of the onset of a runaway polymerisation. The temperature needs to be monitored continuously.
- TBC levels (target >10 ppm wt). At temperatures below 15°C in the tank/container, weekly sampling

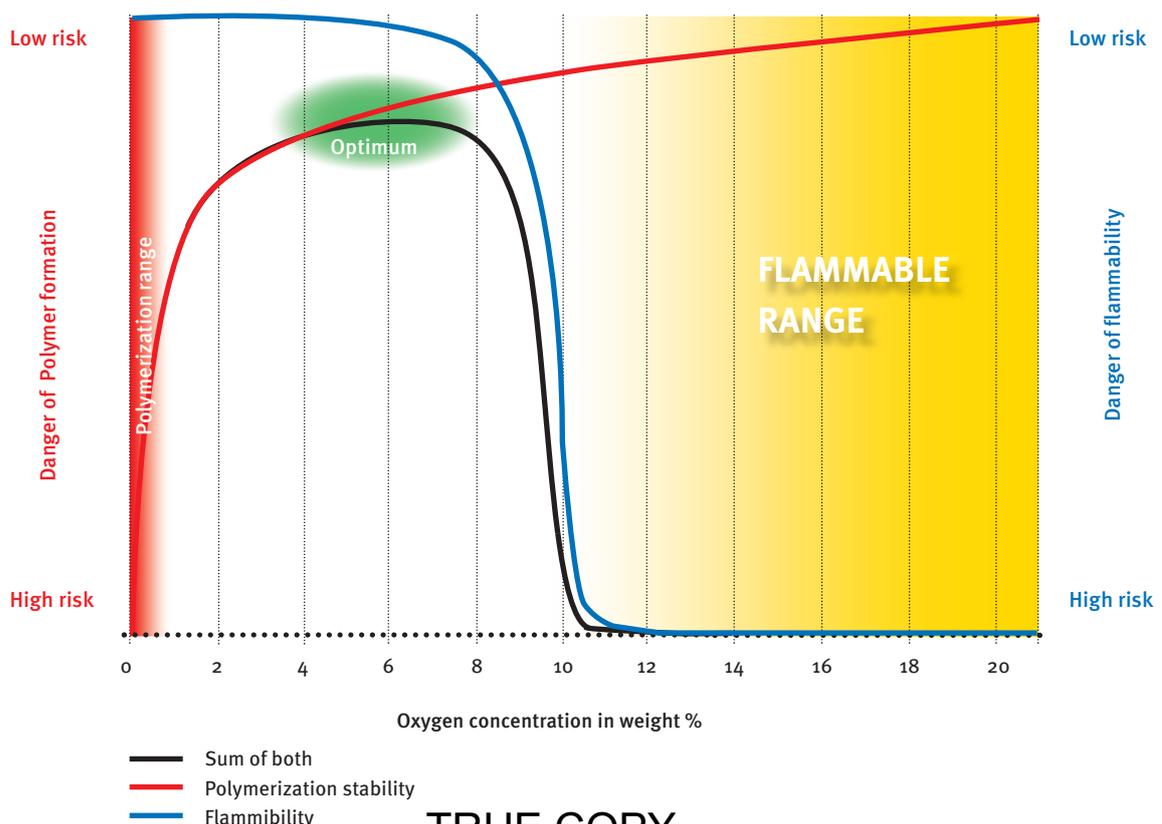
should be sufficient; above 25°C daily sampling is recommended. Normal TBC levels are between 10 and 15 ppm (for some applications higher concentrations are required). Below 10 ppm TBC polymer levels can slowly increase; below 4 ppm the TBC is not effective and accelerated polymerisation will occur. Lower TBC levels can be accepted when the temperature is low and the residence time is short.

- Oxygen levels (3-8 volume % in the vapour phase).

Q2: What is the recommended range of oxygen in the vapour phase of a styrene storage tank?

3-8 volume % oxygen in the vapour phase. Less than 3 vol% is not recommended because the increased risk of polymerization leading to a shorter shelf life. Higher than 8% will lead to an atmosphere above the lower explosion limit. Extra measures have to be taken to prevent sparks.

Figure 6: Optimum oxygen concentration in vapour space of storage tank.



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Q3: What exactly do we define as polymer content – polystyrene or dimers, trimers, oligomers?

The ASTM D2827-04 standard specification of styrene monomer prescribes that the polymer content is analysed by means of ASTM test method D2121 A. This test method utilizes the fact that polystyrene is insoluble in methanol and will not detect dimers and trimers. Any oligomer containing four or more monomer molecules is therefore defined as polymer.

Q4: How often should the styrene be analysed for polymer levels?

Under normal storage conditions: typically 2-3 times/week for product quality.

If product temperature is above 25°C daily. If storage temperature below 15 °C once per week is sufficient.

Q5: How can we ensure thorough mixing of the inhibitor and oxygen if there is insufficient circulation?

When selecting a tank for SM storage, circulation should be a minimum requirement to make sure that:

- Temperature readings are indicative for the bulk
- Inhibitor and oxygen are mixed well with the tank contents.

If tank contents are not homogeneously mixed and, in the undesired situation that the tank is not equipped with facilities to circulate, the following measures can be considered. In order of preference and availability:

- Use circulation pumps
- Try circulation with existing equipment like transfer pumps, minimum flow lines, sample loops
- Connect temporary pump (e.g. compressed air driven)
- Bubbling air (also has the advantage that oxygen is present to enable TBC to be effective) through a utility connection on the tank.
- Bubbling nitrogen through a utility connection on the tank. Beware of asphyxiation. If dissolved oxygen concentrations become too low, this might affect the effectiveness of the inhibitor.

When adding air or nitrogen, it is strongly recommended to contact technical support to make sure that the situation is not made worse, e.g. by over-pressuring the tank.

Q6: What measures can be taken to reduce the rate of polymerisation?

- Reduction of tank temperature (if not yet too high):
- Use refrigeration facilities if available (circulation through cooler). Make sure that the heat exchangers are designed for the temperature of the styrene product.
- Use external water spray. This has a limited effect and unmanned hoses should be used. When the tank is insulated, insulation needs to be removed first, otherwise this has no effect at all. When temperature of the tank is above 60 °C, start with low water flow in order to prevent a vacuum in the tank by styrene condensation.
- Remove insulation.
- Increase inhibitor levels by dosing TBC (up to 100 ppm is acceptable for some customers), aerate the tank contents, and mix bulk contents to make sure that the inhibitor and oxygen are effectively mixed.
- At higher polymerisation rates (i.e. possible HSE risk), mitigate by adding a large enough volume (4:1) of cold inert material (Ethylbenzene (EB), xylenes, toluene) to dilute and cool the styrene. The resulting product cannot be sold and needs to be re-worked or burned as fuel.

When adding EB at 20°C to polymerising SM at 50°C, a (conservative) EB-dosing rate of 7 kg/hr/ton storage is required to absorb the generated heat of reaction, provided that the tank is well-mixed.

This can ONLY be done if the temperature of the tank is well below the boiling point of the diluent (136°C for EB), otherwise it may vaporize or flash off violently, causing damage to the tank or container. Also, the reaction rate at such high temperatures is so high that unfeasibly high EB pump rates are required to absorb the generated heat.

At high temperatures (>52°C), TBC is not an active inhibitor (reaction rates and therefore TBC consumption are high). A Short Stop agent can be added. DEHA and O(H)TEMPO can be used as Short Stop. Be aware that short stop makes the styrene unfit for use by customers and refinishing or discarding is necessary.

Q7: Does a high polymer level always mean the bulk of the product is polymerising?

No.

- Bulk polymerisation can be recognized by a gradual increase of the polymer levels, a gradual depletion of TBC levels and a slight increase in temperature.

- Condensing styrene vapour against tank roof or internals does not contain inhibitor and can form polymer stalactites. These can break off and dissolve in the bulk. This can be recognised as a sudden increase in polymer levels and constant TBC levels.

Sections of piping where there is no flow of material (deadleg) can polymerise over time. Examples of such sections are: low points of pipework, pumps (e.g. spare pumps), sampling systems, etc. When circulating the bulk contents this polymer can dissolve. This leads to a sudden (or gradual, but not following the polymerisation kinetics) increase in polymer content (note: TBC levels and temperature will remain constant).

Q8: Can there be a runaway reaction if there is inhibitor and oxygen present in the styrene?

Not under normal storage conditions, but it is possible in some circumstances that must be avoided, such as:

- Presence of contaminants (e.g. due to insufficient/in-correct cleaning of storage/transportation medium) that initiate polymerisation and overwhelm the inhibition effects of TBC. Known contaminants that initiate polymerisation are acids, peroxides and iron chlorides.
- Presence of rust (particles) inside the tank can form fertile seeds to initiate polymerisation.
- High enough (local) temperature (~ > 40-50°C) (e.g. exposure to heat from an adjacent tank fire). TBC is not active long enough at high temperatures, since the reaction rate and therefore the depletion rate becomes too high.
- Non-homogeneous distribution of the TBC and oxygen in the tank contents: If the TBC concentration is low at certain zones in the tank, this could lead to runaway zones in the bulk contents.

Q9: As polymer levels increase, will there be a concomitant rise in temperature?

That depends:

- No, when the increase in polymer levels is caused by polymer dissolving from tank internals or piping there will be no temperature increase.
- Yes, when the bulk contents are polymerising a 2-3°C temperature increase is observed per 1% SM polymerisation.

However, please note: temperature indicators in styrene tanks may only measure local temperatures and are misreading when the content is not well mixed.

Q10: What polymer and temperature levels are indicative of a runaway reaction?

- That depends on the starting temperature. A better indication would be the temperature increase. A 2-3°C/day temperature increase indicates the onset of runaway reaction.
- The actual runaway is very rapid. As soon as a temperature of 65°C has been reached, it takes about 20 minutes before a complete runaway.
- Starting at 20°C, uninhibited styrene takes 25 days to show a 10°C temperature rise.
- Temperature is a better indication of a runaway than polymer levels. High polymer levels are not necessarily an indication for a runaway, but must just as well be taken seriously.

Make sure that the temperature reading is representative for the bulk temperature. Polymerisation can be ongoing and unnoticed in zones that are not near the thermocouple, if the tank contents are not well-mixed.

Q11: How much time do we have before the reaction enters the “runaway” mode?

The TWB (Time to Water Boiling) graph in Figure 7 can be used to make an evacuation decision: e.g. if is 85 °C, the storage tank may rupture within 100 minutes.

For normal storage tanks, the design pressure will be exceeded during the runaway. The venting capacity is normally insufficient for a runaway.

The ultimate consequence of a runaway in a styrene storage tank, therefore, is a vessel rupture.

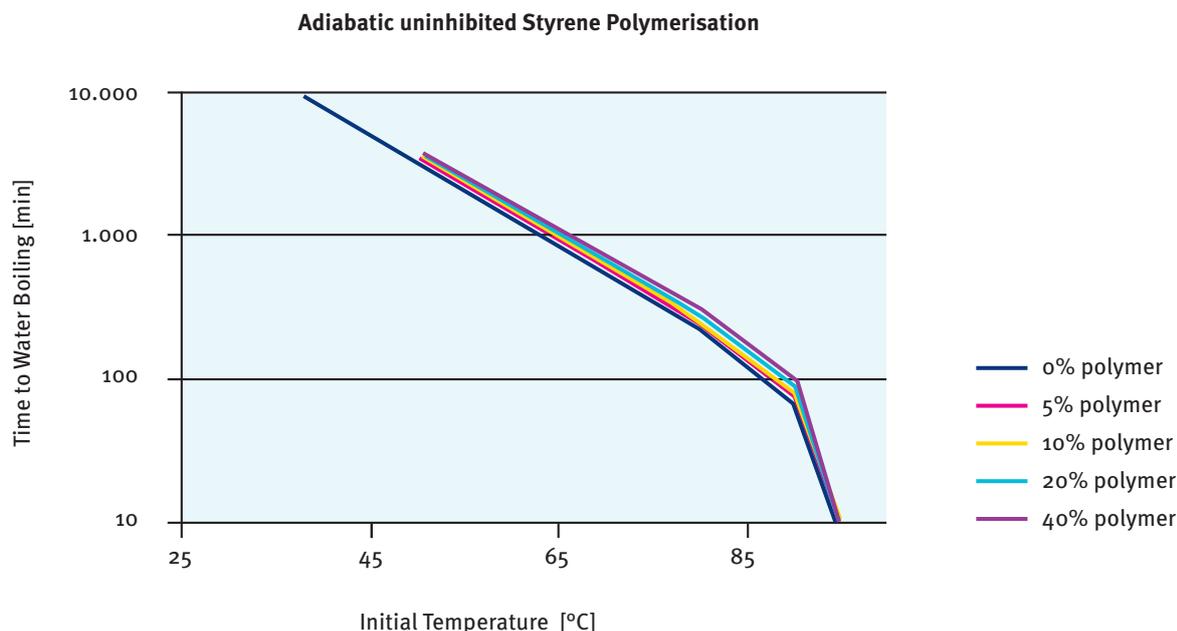
It is possible to predict the moment of vessel rupture when the tank temperature is known. This knowledge can be used to make an informed decision on evacuation of (emergency) staff or notification of third parties (authorities).

Assumptions:

- The tank is adiabatic
- The tank is well-mixed (e.g. the temperature is measured correctly)
- The reaction is uninhibited
- The storage vessel has a design pressure of around 1 bar.
- The styrene is possibly contaminated with water.

The decision to evacuate should be based on the onset of an uncontrollable runaway reaction. The graph below is indicative only and can be useful in the evaluation of evacuation plans. It should NOT be used as a basis to delay evacuations.

Figure 7: Predicted moment of storage vessel failure



Since the final part of the runaway has a very steep dT/dt curve, the time at which the vapour pressure reaches 1 bar is nearly identical for (1%) for water and styrene.

By the same reasoning, the time at which a 1 bar vapour pressure is reached is nearly identical to that of—reaching a 1.5 bar pressure.

Therefore, the time at which normal storage tank fails will - within engineering accuracy - not be determined by the presence of water or by the design pressure.

Furthermore, the build-up of polymers also has a negligible influence.

Figure 7 is conservative (i.e. “safe”) unless:

1. The temperature measurement is not accurate (e.g. in a dead zone),
2. The reaction is accelerated due to radical forming components like hydroperoxides,
3. The tank is heated through other mechanisms (solar radiation, high ambient temperatures, fires etc.)

Figure 6 is over-cautious if:

1. The reaction is inhibited,
2. The tank is cooled,
3. The polymerisation has exceeded 50%.

Q12: What is the colour of high polymer styrene compared to on-spec styrene?

Normally this is colourless (as is on-spec styrene), but various sources of contaminants can colour the product:

- Copper or copper-containing alloys can give a blue-green colour,
- Styrene oxidation products can be highly coloured
- Iron (rust) can give a yellow colour,
- Very high concentrations of polymer can colour the product yellowish.

Being off-spec is therefore not a strong indication of polymerisation.

Q13: At what polymer level does styrene become too viscous to pump?

It depends on the type of pump. In general, a polymer level of 20% is likely to trip a pump that is not designed to move partially polymerised styrene to a high amperage or high power consumption. The pump might not have such a trip and could damage the motor.

If the product is too viscous, it can be diluted (up to 50%) with toluene, xylene or Ethylbenzene.

Appendix 7.

Reception and storage

1. Purpose

The checklist should be used for a self-audit by the customer. It can also be used as a guideline for the safety service of the supplying company. See Section 6.

2. Scope

This scheme shall apply to the reception of styrene by road or rail at all customers.

The principal objective is to ensure that the transfer of styrene from the delivering vehicle to the storage tank can be carried out safely. However, because the storage system and procedures may affect the safety of the unloading operation, these also need to be considered.

The scheme should also be used to:

- a) Assess and record any changes in policy, attitudes or equipment since the previous check.
- b) Obtain customer's comments on the transport operation and equipment being used.

The attached guidance notes provide an explanation of the check-list, and recommended minimum standards in certain cases.

3. Styrene Unloading / Storage Checklist

CUSTOMER:

DATE:

ADDRESS:

PERSONS INTERVIEWED:

VISITED BY:

3.1. The Unloading Area

1. Ease of access,
2. Housekeeping,
3. Separation of other activities,
4. Ability to mobilise road tanker/rail car in case of emergency,

5. Facilities to isolate area and restrict access,
6. Firefighting systems,
7. Electrical Area classification and Electrical classification of equipment,
8. Define the minimum safety distances between the off-loading point, storage, and ignition sources.
9. Hoses/unloading arms,
10. Earthing point,
11. Protection against pipe damage,
12. Other vehicles and trucks movements,
13. Are hoses on the truck clean and qualified for styrene?
14. Spillage controls systems with styrene resistant surface and sufficient containment volume,
15. Hazard labelling of unloading points,
16. Visual and audible alarm,
17. Declaration of suitability, approval by local authorities if legally required.

3.2. The Unloading Personnel and Equipment

1. The presence of customer's operator/ driver self-unloading,
2. Operator's experience, training and seniority,
3. Deputy availability,
4. Hose testing and renewal policy,
5. Fixed unloading arm testing and maintenance,
6. Availability of suitable safety equipment,
7. Antifall guard or fall arrestors for work on top of the vehicle,
8. Communication system,
9. Use of dedicated loading / unloading lines.

3.3 The Unloading Operations

1. Written procedures,
2. Hose purging and leak testing,
3. Sampling procedure,
4. Atmospheric/personal monitoring,
5. Method of unloading (for example nitrogen pressure, pump - pump preferred, flow velocities to prevent static build-up),
6. Safeguards for pump,
7. Emergency response,
8. Emergency stop,
9. Sufficient tank venting capacity.

3.4 The Storage Tank

Site

1. Secondary containment (bund),
2. Shared? If shared, with what?
3. Separation distances,
4. Emergency disposal facilities.

Construction

1. Construction materials,
2. Insulated,
3. Uninsulated,
4. Refrigerated,
5. Firefighting systems,
6. Earthed,
7. Agitation,
8. Blanketing,
9. Fire protection,
10. Internal coating tanks,
11. Design pressure,
12. Maximum allowed working pressure,
13. Date and type of last test, inspection,
14. Dip inlet pipe with siphon breaker,
15. Circulation loop for air, TBC, temperature distribution.

Relief Valves

1. Separate,
2. Combined with interlock,
3. Size,
4. Venting to: (stack, scrubber, flare, other),
5. Vacuum relief valves,
6. Flame arrestors,
7. Nitrogen purge vents.

Instrumentation

1. Nitrogen blanketing pressure,
2. Control points:
 - a. Temperature,
 - b. Pressure,
 - c. Level.
3. Are control and alarms independent?

Monitoring of Storage

1. Temperature,
2. Pressure,
3. Level,
4. Piping,
5. Pumps,
6. Valves,
7. Gaskets,
8. Hoses.

4. Storage Tank to Process

Precautions to prevent process streams contaminating storage vessels.

4.1 Procedures

There should be written procedures available for the following:

1. Unloading styrene,
2. Testing, inspection and maintenance of equipment,
3. Emergency procedures.

5. Customers Comments

Guidance notes for styrene unloading/storage checklist:

The reference numbers shown below relate to items shown on the styrene unloading / storage checklist.

5.1. The Unloading Area

1. There should be sufficient space for easy access of vehicles.
2. Unless it is connected to the unloading facilities, it should be possible for the vehicle to be removed from the unloading area in the case of an emergency.
3. Barriers, warning notices are required. Special consideration may need to be given to prevent shunting close to the unloading area.
4. A foam or powder-based system is recommended.
5. This should be in accordance with national regulations.
6. Unloading arms are preferred to hoses.
7. The earthing point should be checked on a regular basis.

5.2. The Unloading Personnel and Equipment

1. The customer's operator must be present during off-loading and maintain control of the styrene unloading area. If the driver unloads the cargo, he should be trained and certified by the receiving party, to operate the installation according to the unloading procedures.
2. There should be at least two trained deputies to provide cover for illness and holidays.
3. Consider general protective equipment. Goggles should be worn. A safety shower and eye fountain should be sited adjacent to the unloading area.

5.3. The Storage Tank

The sizing of styrene storage tanks should be the smallest compatible with shipping and receiving requirements.

Storage times in excess of 3 to 6 months should be avoided to minimize degradation of styrene quality.

5.4. Construction

Construction materials:

Carbon steel and stainless steel are suitable for handling styrene.

No copper nor material containing copper as an alloy element should contact liquid.

Copper can discolour the styrene and has been known to cause polymerisation in some applications).

Insulation and Refrigeration:

Styrene storage tanks do not normally require insulation or refrigeration unless extremely high temperatures are likely to be encountered.

Blanketing

Blanketing of tanks for fire protection should be considered if ambient temperatures warrant this ($T > 30^{\circ}\text{C}$). Exothermic polymer formation is prevented by oxygen, so a minimum level of 3-8% volume of oxygen in the vapour phase is recommended. TBC should be added at a level depending on the residence time, but minimum at all times to be 5 ppm, to prevent subsequent poly-peroxide formation. The liquid should be circulated for proper distribution of both oxygen and TBC.

Fire Protection

The provision of fire protection systems, e.g. foam, should be considered where appropriate.

This includes water spray systems to isolate from other fires near the tank.

Earthing

Adequate provision should be made to allow dissipation of static electricity.

A certified lightning protection system must be installed.

Internal Coating

Internal coatings are not required for styrene storage tanks, but can help to minimise

polymer formation. Inorganic zinc silicate linings can be used. If a tank lining is used, it is

important to ensure that a satisfactory tank earthing arrangement is provided.

5.5. Relief Valves

There should be a rigorous procedure for regularly checking for signs of polymer formation.

6. Instrumentation and Monitoring

Level indicators and level alarms are advised to prevent tanks overfilling. Consideration should be given to extra high level interlocks to shut off the tank feed

Pressure and temperature indications are also advised and should be monitored regularly.

An interlock of high level alarm with unloading pump shutdown is recommended.

7. Piping

Carbon steel, stainless steel may be used.

All low points should be provided with drains. Blanks should be fitted to open ends.

8. Pumps

Centrifugal pumps are preferred for styrene service. For environmental considerations, canned motor pumps or magnetically driven pumps could be considered.

Double mechanical seals with styrene-compatible antifreeze flush are also possible.

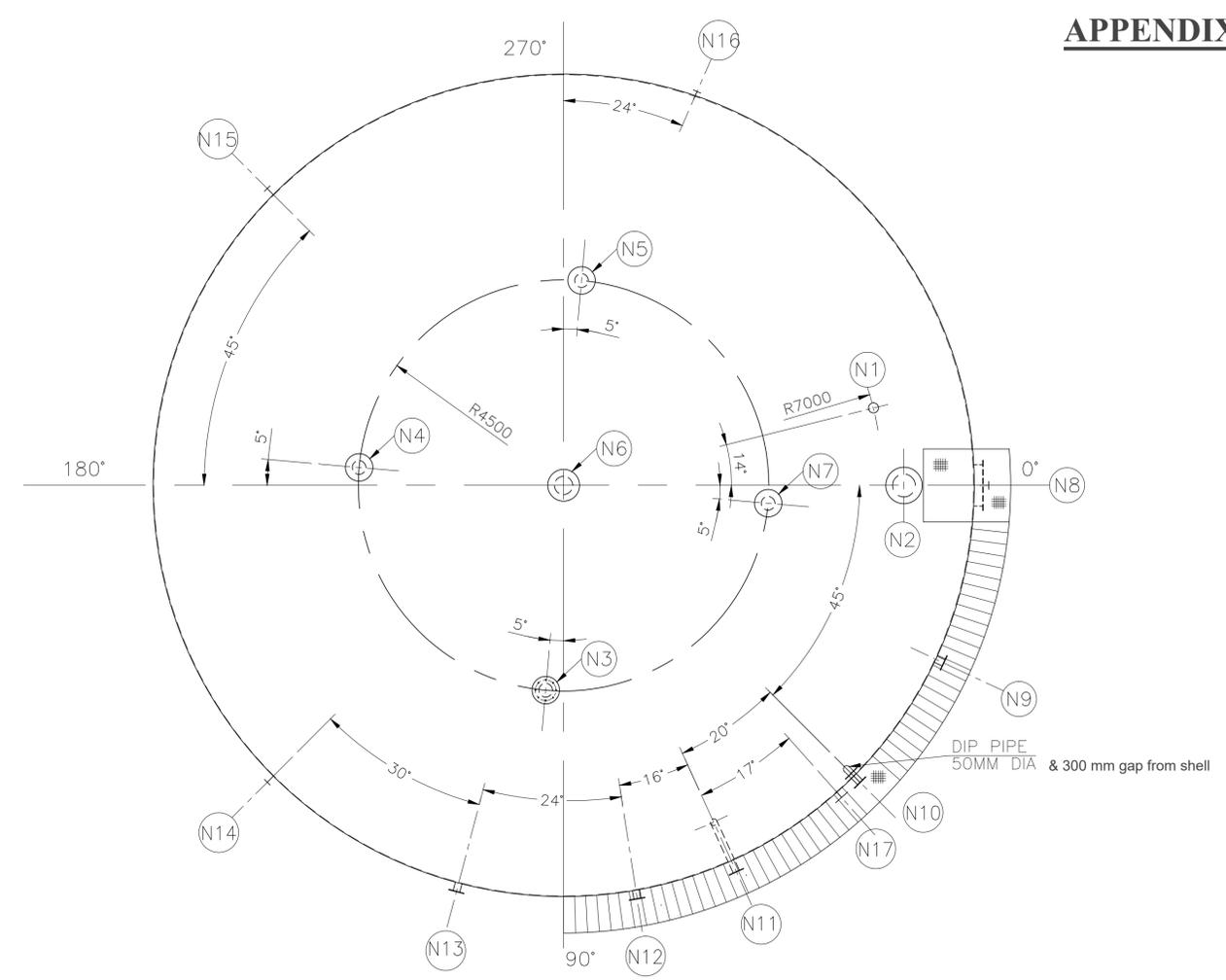
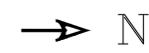
9. Valves

Gate, globe, angle or ball valves may be used in styrene service. Stem packing should be graphite-based coil, modified PTFE, or equivalent. Bonnet gaskets may be soft iron, graphite or spiral-wound. For ball valves, Teflon seats are acceptable.

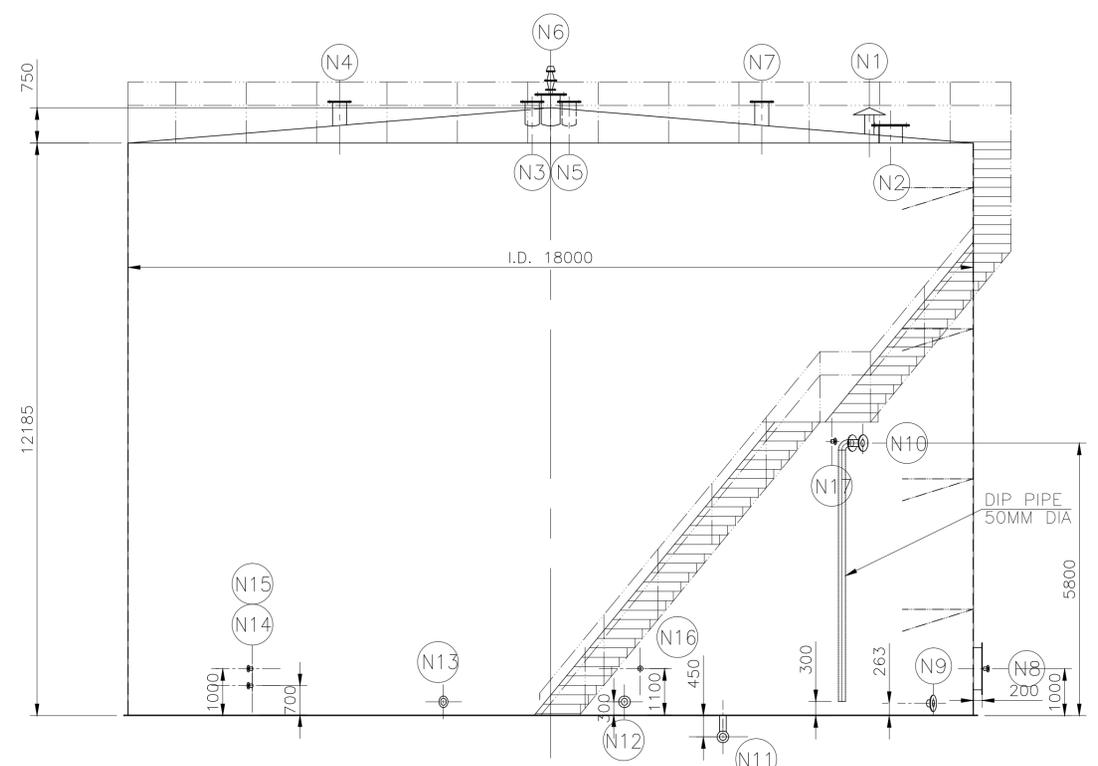
10. Hoses

The use of hoses should be avoided, but if needed for loading or unloading operations, they should be styrene-resistant line armoured austenitic stainless steel flex hose or equivalent. Hoses should be inspected by carrying out a pressure and conductivity test at least every 12 months.

APPENDIX - 2



PLAN



VIEW FROM EAST

1	ITEM No.	1267
2	QUANTITY	1
3	DESIGN CODE	IS 803
4	WIND PRESSURE	200 Kg/cm ² (g)
5	DESIGN TEMP	50 °C
6	DESIGN PR	250 to 1000 mm WG
7	OPERATING TEMP	Ambient
8	OPERATING PR	Atm
9	TEST PR	Full of Water
10	CORR ALLOWANCE	Shell 3 mm, Roof 1 mm
11	JOINT EFFICIENCY	0.85
12	RADIOGRAPHY	10% Spot + T's
13	NOMINAL VOLUME	3100 KL
14	PROCESS FLUID	Styrene
15	DENSITY	900 kg/m ³
16	PETROLEUM CLASS	B
17	TEST FLUID	Water
18	MAX DRAW RATE	100 KL/hr
19	MAX FILL RATE	100 KL/hr

MATERIAL OF CONSTRUCTION

A	BOTTOM CENTRE PLATES	IS 226
B	BOTTOM ANNULAR PLATES	IS 226
C	SHELL	IS 226
D	ROOF PLATES	IS 226
E	ROOF CORNER RING	IS 226
F	ROOF STRUCTURE	IS 226
G	FLANGES	SA 105
H	PIPES	SA 53 Gr A/B
I	FASTENERS	IS 1367 Gr 6.8
J	ANCHOR BOLTS & NUTS	IS 1367
K	GASKETS	IS 2712 Gr A/1
L	INTERNALS	IS 226
M	MANHOLE	IS 226
N	SUPPORTS	IS 226

NOTES:—

- CAPACITY OF TANK : 3100 KL
- MATERIAL : IS 226
- ALL DIMENSIONS ARE IN MM ONLY, UNLESS OTHERWISE SPECIFIED.

N17	SPARE	25 NB	CLOSE
N16	TEMPERATURE GAUGE	25 NB	CLOSE
N15	SPARE	25 NB	CLOSE
N14	TEMPERATURE GAUGE	25 NB	CLOSE
N13	REFRIGERATION OUTLET	100 NB	CLOSE
N12	STYRENE INLET	200 NB	CLOSE
N11	DRAIN	80 NB	CLOSE
N10	REFRIGERATION INLET	100 NB	CLOSE
N9	STYRENE OUTLET	150 NB	CLOSE
N8	MAN HOLE (SHELL) / LEVEL TRANSMITTER	900 NB	25 NB
N7	SPARE	300 NB	CLOSE
N6	FLAME ARRESTER / BREATHER	400 NB	50NB FLAME ARRESTER
N5	SPARE	300 NB	CLOSE
N4	SPARE	300 NB	CLOSE
N3	SPARE	300 NB	CLOSE
N2	MANHOLE / FOAM POROUS	500 NB	CLOSE
N1	VENT / DIP HATCH	200 NB	OPEN
NOZZLE	DESCRIPTION	SIZE	REMARKS

L.G. POLYMERS INDIA PVT. LTD.
R.R.VENKATAPURAM, VISAKHAPATNAM - 530 029

**GENERAL ARRANGEMENT AND
DETAIL OF STYRENE TANK 1267 (M6)**

DRAWN	G. SANTOSH	SCALE	NTS
CHECKED	S.PRADEEP/ALIP KUMAR	DATE	
APPROVED	S.S.PRASANTH	SIZE	A2
DRAWING NO.	LGPI/SMH/M6	REV. No.	3



Work Instructions Manuals

Name : Chemical addition to SM Storage tanks

IMS Clause	ORG. ISSUE DATE	REV. NO. / REV. DATE	Plant / Dept.	PAGE NO.
WIS / 8.5.1 / 019	01.10.2019	00	SMH	1

Scope – Adding of TBC in SM storage tanks in SMH Tank Farm & EIPL

Responsibility – Area Operator

SMH Tank Farm

- Calculate TBC quantity to be added in the tanks
- Take the TBC quantity in a bucket and dissolve in styrene
- Take around 200 kgs of styrene in day tank
- Pour the dissolved TBC in to day tank
- Then start the unloading pump and pump the whole material in to SM storage tank
- Then fill the day tank with pure SM and again pump the material in to SM storage tank (M5 & M6).
- After 2-Hours , offer the sample to QAD(Top & Bottom) & check the results.
- If TBC within limits, Ok or else again repeat the same.

EIPL Tanks

- In case of EIPL tanks calculate TBC quantity to be added in the tanks
- Send required quantity of TBC to EIPL
- Our operator at EIPL Recieves TBC and Dissolve the TBC In the bucket
- Dissolved TBC will be carried to the top of the tank manually and pour the content from the dip hatch.
- After 2-Hours , offer the sample to QAD(Top & Bottom) & check the results.
- If TBC within limits, Ok or else again repeat the same.

Date	Prepared	Approved
01.10.2019		Approved

**GOVERNMENT OF ANDHRA PRADESH
ABSTRACT**

HM & FW Dept. - Containment, Control and Prevention of spread of COVID - 19 - Lock down till 31st March, 2020 in the State of Andhra Pradesh - Notification under Epidemic Disease Act, 1897 - Issued

HEALTH, MEDICAL & FAMILY WELFARE (B2) DEPARTMENT

G.O.Rt.No.209

Dt: 22.03.2020

Read the following :

1. G.O.Rt.No.189, HM & FW (B2) Dept. Dt:13.03.2020.
2. G.O.Rt.No.202, HM & FW (B2) Dept. Dt:18.03.2020.
3. G.O.Rt.No.204, HM & FW (B2) Dept. Dt:19.03.2020.

ORDER :

The following notification shall be published in the extra ordinary issue of A.P. Gazette.

NOTIFICATION

In exercise of the powers contained under Sec 234 of Epidemic Disease Act, 1897, the Governor of Andhra Pradesh hereby issues following measures for containment of COVID-19.

1. WHO has declared COVID19 a global pandemic. Since the onset of preventive measures 11,670 foreign returnees to the state have been placed under medical surveillance. Of these 10,091 are placed under home isolation, 24 are hospitalized and 1,555 have completed home isolation of 28 days. So far 6 cases have tested positive, one each in districts of Nellore, East Godavari, Krishna, Prakasam and 2 in Visakhapatnam.

2. While, vide GO Rt.No. 202 and GO Rt. No. 204 multiple restriction and social distancing measures have been communicated, it is imperative that in proactive manner a state-wide lockdown is observed to prevent onset of community transmission of the Corona-virus. Therefore, in continuation to the measures enunciated in GOs cited above the following measures to ensure that such a lockdown will come into force with immediate effect across the state of Andhra Pradesh up to 31st March 2020:

- i. No public transport including inter-state transport services shall be permitted. The exception will include transport of all kinds to and fro from hospitals, airports & railway stations etc.
- ii. All non-essential commercial shops shall be shut down.
- iii. All non-essential offices, factories, workshops, go-downs etc. if operated should do so with skeletal staff.
- iv. All foreign returnees are directed to remain under strict home quarantine for a period of 14 days or as advocated by local Health Authorities (Collectors to monitor and update on online portal).
- v. Police will ensure Beat Vigilance System regarding all foreign returnees across the state. For this, police should take help of MahilaSamrakshna Karyadarshi (mahila police).
- vi. General public are required to stay at home and come out only for basic services while strictly following social distancing (2m distance between individuals) guidelines issued earlier.
- vii. Any congregation of more than 10 persons is prohibited in public places.
- viii. A 100 bedded Quarantine / Isolation facility should be established at each assembly constituency level.

P.T.O

:2:

- ix. Each district headquarters shall have 200-300 bed Tertiary Care Treatment facility dedicated for COVID-19 treatment in coordination with private sector.
- x. Collectors will maintain strict vigilance on essential commodities and medicines. Clear advertisements regarding rates & stocking in this regard shall be communicated and any violation by individuals/establishments shall be dealt strictly under relevant provisions of the IPC. A toll free number should be set up by District Collectors for complaints in this regard
- xi. Farmers and individuals involved in production of food grains/essential commodities will be allowed to take up their activities by maintaining social distancing norms.

3. However, the following establishments providing essential services shall be excluded from the above restrictions:

- a. Offices charged with law and order and magisterial duties
 - i. Collector
 - ii. Joint Collector
 - iii. Sub Collector / RDO
 - iii. MRO
- b. Police, Health, Urban Local Bodies, Fire, Electricity, Water and Municipal Services, Bank/ATM, Print, Electronic and Social Media.
- c. Food, Groceries, Milk, Bread, Fruit, Vegetable, Meat, Fish and their transportation related activities and warehousing.
- d. Hospitals, Pharmacies, Optical stores, Pharmaceuticals manufacturing and their transportation related activities
- e. Telecom & Internet Services including IT&ITeS, Postal services
- f. Supply chain and related transportation of essential goods
- g. e-Commerce (delivery) of all essential goods including food, pharmaceutical and medical equipment
- h. Take away/ home delivery restaurants and hotels.
- i. Petrol pumps, LPG gas, Oil agencies, their go-downs and transportation related activities.
- j. Production and Manufacturing Units which require continuous process may continue to function, after obtaining required permission from the Collector.
- k. Manufacturing units engaged in production of essential commodities
- l. Private establishments that support the above services or are linked to the efforts for containment of COVID-19 will remain open.

4. District Collector shall be the competent authority to decide if any produce / service is essential in nature or not.

5. District Administration should appeal to general public to ensure observance of social distancing norms in public places and appropriate sanitary / distancing measures in private sphere. This appeal should lay special focus on the elderly (above 60 yrs) and those with flu like symptoms, medical complications like asthma, BP, cardio vascular complications etc.

6. While the lockdown as enunciated above should be initiated with immediate effect, the district administration should continue to focus on the containment strategy being practised thus far involving tracking the dissemination of a disease within a community through tracking of foreign returnees / suspect cases, and then using isolation and individual quarantines to keep people who have been infected by or exposed to the disease from spreading it.

:3:

7. District Collectors, Joint Collectors, Police Commissioners, SPs, Municipal Commissioners, Sub Collectors, RDOs, DM&HOs, Tahsildars and MPDOs are hereby authorized to take all necessary actions for enforcement and implementation of the aforesaid measures. Local police shall render necessary assistance as and when requisitioned by the aforementioned officers.

8. Any person found violating the containment measures; shall deemed to have committed an offence punishable under section 188 of Indian Penal Code (45 of 1860). Strict compliance with aforementioned measures is warranted.

(BY ORDER AND IN THE NAME OF GOVERNOR OF ANDHRA PRADESH)

**NILAM SAWHNEY
CHIEF SECRETARY TO GOVERNMENT**

To

The Commissioner, Printing, Stationery & Purchase, Vijayawada (with a request to publish the notification in extraordinary Gazette)

All the District Collectors in the State.

All the Municipal Commissioners in the State.

The Principal Secretary, T.R. & B., Secretariat.

} with a request

The Spl, Chief Secy., Revenue (CT&Excise) Dept.

} to issue further

The Principal Secretary, Home Dept.

} guidelines to

The Principal Secretary, Revenue Dept.

} operationalize

The Principal Secretary, L.E.T. & F. Dept., Secretariat

} the instructions

The Principal Secretary, PR&RD Dept.

} issued in the G.O.

The Principal Secretary, I&I Dept.

}

The Principal Secretary, MA&UD Dept.

}

The Director General of Police, Mangalagiri.

}

The Commissioner, I&PR Dept.

}

All District Superintendents of Police in the State of A.P.

The Commissioner of Police, Visakhapatnam, Vijayawada.

The Commissioner of Public Transport Department.

All HODs of H.M. & F.W. Dept.

Copy to:

OSD to Dy.CM (HFW & ME)

PS to CS/ PS to Addl.C.S. to CM

PS to Principal Secretary (Poll), GAD PS

to Commissioner, I & P.R.

//FORWARDED:: BY ORDER//

SECTION OFFICER

LG Polymers India Pvt. Ltd.

Regd. Office & Works : R.R. Venkatapuram, Visakhapatnam - 530 029, India
CORPORATE IDENTITY NUMBER (CIN) : U25203AP1996PTC025917

ISO 9001:2015 &
ISO 14001:2015
BUREAU VERITAS
Certification



Visakhapatnam	91-891-2520455 ~ 458	Fax : 91-891-2520528
Mumbai	91-22-61085300 ~ 332	Fax : 91 - 22-61085344
Gurgaon	91-0124-4692700 ~ 11	Fax : 91-0124-4692701
Kolkata	91-33-25797977 & 78	
Chennai	91-44-26650201	Fax : 91-44-43870203
Vijayawada	91-9849170565	
Pune	91-020-66487600	

Ref: LGPI/03/2020

Date: 23.03.2020

**The District Collector & Magistrate
Visakhapatnam**

Respected Sir,

Sub: Request permission for Operating our Manufacturing Industry - Reg
Ref: Government of AP G.O.Rt.No. dt. 22.03.2020

We, LG Polymers India Pvt. Limited, situated in RR Venkatapuram (near Gopalapatnam), Visakhapatnam is a South Korean MNC Company. We manufacture Polystyrene & expandable polystyrene using the main raw material Styrene Monomer (SM) which is imported from south East Asian countries. We employ about 500 employees both permanent & contract workers.

Ours is a petrochemical plant classified under MAH category, continuous polymerization of styrene monomer, operating on 24 X 7 basis under A, B, C & General shifts.

Imported styrene monomer (thru' Visakhapatnam port) is stored in leased transit terminal at M/s. East India Petroleum Ltd.(EIPL) Visakhapatnam. We regularly transfer SM to our plant thru' road tankers and currently we are having around 7000 MT of SM at EIPL which need to be shifted to plant location considering the hazardous nature of the chemical (stagnation of SM leads to auto-polymerization / explosion).

Hence we request your good offices to permit us to continue plant operations in view of the nature of the industry.

Sir, we humbly request you to give permission to our Industry to enable us to run the operations with skeletal staff (about 70% reduction) considering the nature of polymer industry.

However, we assure you that we have taken all necessary precautions to maintain social distance, disinfecting our premises following the guidelines issued by the govt. We established the practice of monitoring the health condition of all our employees at the entrance of the factory gate.

We request your kind permission.

Thanking you,

Your faithfully,
For LG Polymers India Pvt. Limited


P.P.C. Mohan Rao
Director (Operations)

TRUE COPY
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**GOVERNMENT OF ANDHRA PRADESH
ABSTRACT**

HM & FW Department – Containment, Control and Prevention of spread of COVID-19 – **“Lockdown” till 14th April, 2020** in the State of Andhra Pradesh under Disaster Management Act, 2005 –Orders- Issued.

HEALTH, MEDICAL & FAMILY (B2) DEPARTMENT

G.O.Rt.No.216,

Dated: 24.03.2020

Read the following:

1. G.O.Rt.No.189, HM & FW (B2) Dept. Dt: 13.03.2020.
2. G.O.Rt.No.202, HM & FW (B2) Dept. Dt: 18.03.2020.
3. G.O.Rt.No.204, HM & FW (B2) Dept. Dt: 19.03.2020.
4. G.O.Rt.No.209, HM & FW (B2) Dept. Dt: 22.03.2020.
5. G.O.Rt.No.210, HM & FW (B2) Dept. Dt: 23.03.2020.
6. G.O.Rt.No.211, HM & FW (B2) Dept. Dt: 23.03.2020.
7. National Disaster Management Authority Order No.1-29/2020-PP (P1. II), dt.24.3.2020.
8. MHA, GoI Order No.40-3/2020-DM-I(A), Dt. 24.3.2020.

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ORDER:

In the reference 7th read above, the National Disaster Management Authority (NDMA) has issued orders directing the Ministries/ Departments of Government of India and the State/Union Territory Governments and State/Union Territory Authorities to take effective measures to prevent the spread of COVID-19 in the country.

2. In compliance of the Orders 7th read above, in the reference 8th read above, under Section 10(2)(1) of the Disaster Management Act, the Ministry of Home Affairs, Government of India, New Delhi have issued Orders directing the Ministries/ Departments of Government of India and the State/Union Territory Governments and State/Union Territory Authorities to take effective measures to prevent the spread of COVID-19 in the Country and the Order shall remain in force, in all parts of the Country, for a period of 21 days w.e.f. 25.03.2020.

3. Therefore, all the District Collectors, Joint Collectors, Police Commissioners, SPs, DM&HOs, Municipal Commissioners, Sub Collectors, RDOs, MROs and MPDOs are hereby instructed to strictly implement the guidelines as per Annexure to the Order mentioned vide reference 8th read above. This Order shall remain in force in all parts of the State for a period of 21 days with effect from 25.03.2020. For implementing the containment measures, the District Magistrate will deploy Executive Magistrates as Incident Commanders as specified in the above guidelines.

4. The Order mentioned vide reference 8th read above shall be implemented along with various orders issued earlier by the State Government for **“Lockdown”** in the State for containing the spread of COVID-19.

(BY ORDER AND IN THE NAME OF THE GOVERNOR OF ANDHRA PRADESH)

**NILAM SAWHNEY,
CHIEF SECRETARY TO GOVERNMENT**

To
All the District Collectors in the State.

(p.t.o)

-2-

All the Special Chief Secretaries/Prl. Secretaries/Secretaries.
The D.G.P., Mangalagiri.
The Commissioner of Police, Visakhapatnam, Vijayawada.
All District Superintendents of Police.
All Municipal Commissioners in the State.
All HODs of H.M. & F.W. Dept.
All the DM& HOs in the State.

Copy to:

PS to CS/ PS to Addl.C.S. to CM
OSD to Dy.CM (HFW & ME).
PS to Spl.C.S. to Govt., HM&FW Department.
PS to Principal Secretary (Poll), GAD.
PS to Commissioner, I & P.R. Department.
SC/SF.

//FORWARDED: BY ORDER//**SECTION OFFICER****(Contd...Annexure)**

Annexure to G.O.Rt.No.216, HM&FW(B2)Deptt., Dt.24.03.2020

Guidelines on the measures to be taken for containment of COVID-19 Epidemic in the State:

1. Offices of the Government of India, its Autonomous/ Subordinate Offices and Public Corporations shall remain closed.

Exceptions:

Defence, central armed police forces, treasury, public utilities (including petroleum, CNG, LPG, PNG), disaster management, power generation and transmission units, post offices, National Informatics Centre, Early Warning Agencies.

2. Offices of the State/ Union Territory Governments, their Autonomous Bodies, Corporations, etc. shall remain closed.

Exceptions:

- a.** Police, home guards, civil defence, fire and emergency services, disaster management, and prisons.
- b.** District administration and Treasury
- c.** Electricity, water, sanitation.
- d.** Municipal bodies—Only staff required for essential services like sanitation, personnel related to water supply etc

The above offices (Sl. No 1&2) should work with minimum number of employees. All other offices may continue to work-from-home only.

3. Hospitals and all related medical establishments, including their manufacturing and distribution units, both in Public and Private sector, such as dispensaries, chemist and medical equipment shops, laboratories, clinics, nursing homes, ambulance etc. will continue to remain functional. The transportation for all medical personnel, nurses, para-medical staff, other hospital support services be permitted.

4. Commercial and private establishments shall be closed down.

Exceptions:

- a.** Shops, including ration shops (under PDS), dealing with food, groceries, fruits and vegetables, dairy and milk booths, meat and fish, animal fodder. However, district authorities may encourage and facilitate home delivery to minimize the movement of individuals outside their homes.
- b.** Banks, insurance offices, and ATMs.
- c.** Print and electronic media
- d.** Telecommunications, internet services, broadcasting and cable services. IT and IT enabled Services only (for essential services) and as far as possible to work from home.
- e.** Delivery of all essential goods including food, pharmaceuticals, medical equipment through E-commerce.
- f.** Petrol pumps, LPG. Petroleum and gas retail and storage outlets.

(Cont...p.2)

-2-

- g.** Power generation, transmission and distribution units and services
- h.** Capital and debt market services as notified by the Securities and Exchange Board of India.
- i.** Cold storage and warehousing services.
- j.** Private security services

All other establishments may work-from-home only.

5. Industrial Establishments will remain closed.

Exceptions:

- a.** Manufacturing units of essential commodities.
 - b.** Production units, which require continuous process, after obtaining required permission from the State Government
- 6.** All transport services — air, rail, roadways — will remain suspended.

Exceptions:

- a.** Transportation for essential goods only.
 - b.** Fire, law and order and emergency services.
- 7. Hospitality Services to remain suspended.**
- Exceptions:**
- a.** Hotels, homestays, lodges and motels. which are accommodating bursts and persons stranded due to lockdown, medical and emergency staff air and sea crew.
 - b.** Establishments used/ earmarked for quarantine facilities.
- 8.** All educational, training, research, coaching institutions etc shall remain closed.
- 9.** All places of worship shall be closed for public. No religious congregations will be permitted, without any exception.
- 10.** All social/ political/ sports/ entertainment/ academic/ cultural/ religious functions/ gatherings shall be barred.
- 11.** In case of funerals, congregation of not more than twenty persons will be permitted.
- 12.** All persons who have arrived into India after 15.02.2020, and all such persons who have been directed by health care personnel to remain under strict home/ institutional quarantine for a period as decided by local Health Authorities, failing which they will be liable to legal action under Sec 188 of the IPC.
- 13.** Wherever exceptions to above Containment measures have been allowed, the originations/employees must ensure necessary. Precautions against COVID-19 Virus, as well as social distance measures, as advised by the Health Department from time to time.

(Cont...p.3)

-3-

14. In order to implement these containment measures, the District Magistrate will deploy Executive Magistrate as incident Commanders in the respective local jurisdictions. The Incident Commander will be responsible for the overall implementation of these measures in their respective jurisdictions. All other line Department officials in the specified area will work under the directions of such incident commander. The Incident commander will issue passes for enabling essential movements as explained

15. All Enforcing Authorities to note that these strict restrictions fundamentally relate to movement of people, but not to that of essential goods.

16. The Incident Commanders will in particular ensure that all efforts for mobilisations of resources, workers and material for augmentation and expansion of Hospital infrastructure shall continue without any hindrance.

17. Any person violating these containment measures will be liable to be proceeded against as per the provisions of Section 51 to 60 of the Disaster Management Act, 2005, besides Legal action under Sec. 188 of the IPC (as per Appendix).

18. The above Containment measures will remain in force, in all parts of the Country, for a period of 21 days with effect from 25.03.2020.

APPENDIX

(I) OFFENCES AND PENALTIES OF THE DISASTER MANAGEMENT ACT, 2005

51. Punishment for obstruction, etc- Whoever, without reasonable cause-

(a) Obstructs any officer or employee of the Central Government or the State Government, or a person authorised by the National Authority or State Authority or District Authority in the discharge of his functions under this Act; or

(b) Refuses to comply with any direction given by or on behalf of the Central Government or State Government or the National Executive Committee or the State Executive Committee or the District Authority under this Act, shall on conviction be punishable with imprisonment for a term which may extend to one year or with fine, or with both, and if such obstruction or refusal to comply with directions results in loss of lives or imminent danger thereof, shall on conviction be punishable with imprisonment for a term which may extend to two years.

52. Punishment for false claim-

Whoever knowingly makes a claim which he knows or has reason to believe to be false for obtaining any relief, assistance, repair, reconstruction or other benefits consequent to disaster from any officer of the Central Government, the State Government, the National Authority, the State Authority or the District Authority, shall, on conviction be punishable with imprisonment for a term which may be extended to two years, and also with fine.

(Cont...p.4)

-4-

53. Punishment for misappropriation of money or materials, etc-

Whoever, being entrusted with any money or material or otherwise being, in custody of or dominion over, any money or goods, meant for providing relief in any threatening disaster situation or disaster, misappropriates or appropriates for his own use or disposes of such money or materials or any part thereof or wilfully compels any other person so to do, shall on conviction be punishable with imprisonment for a term which may extend to two years, and also with fine.

54. Punishment for false warning-

Whoever makes or circulates a false alarm or warning as to disaster or its severity or magnitude, leading to panic, shall on conviction, be punishable with imprisonment which may extend to one year or with fine

55. Offences by Departments of the Government-

(1) Where an offence under this Act, has been committed by any Department of the Government, the head of the Department shall be deemed to be guilty of the offence and shall be liable to be proceeded against and punished accordingly unless he proves that the offence was committed without his knowledge or that he exercised all due diligence to prevent the commission of such offence.

(2) Notwithstanding anything contained in sub-section (1), where an offence under this Act, has been committed by a Department of Government and it is proved that the offence has been committed with the consent or connivance of or is attributable to any neglect on the part of, any officer, other than the head of the Department, such officer shall be deemed to be guilty of that offence and shall be liable to be proceeded against and punished accordingly.

56. Failure of officer in duty or his connivance at the contravention of the provisions of this Act – Any officer, on whom any duty has been imposed by or under this Act and who ceases or refuses to perform or withdraws himself from the duties of his office shall, unless he has obtained the express written permission of his official superior or has other lawful excuse for so doing, be punishable with imprisonment for a term which may extend to one year or with fine.

57. Penalty for contravention of any order regarding requisitioning – If any person contravenes any order made under Section 65, he shall be punishable with imprisonment for a term which may extend to one year or with fine or with both.

58. Offence by Companies – (1) Where an offence under this Act has been committed by a company or body corporate, every person who at the time the offence was committed, was in charge of and was responsible, to the company, for the conduct of the business of the company, as well as the company, shall be deemed to be guilty of the contravention and shall be liable to be proceeded against and punished accordingly. Provided that nothing in this sub-section shall render any such person liable to any punishment provided in this Act, if he provides that the offence was committed without his knowledge or that he exercised due diligence to prevent the commission of such offence, (2) Notwithstanding anything contained in sub-section (1), where an offence under this Act has been committed by a company, and it is proved that the offence was committed with the consent or connivance of or is attributable to any neglect on the part of any director, manager, secretary or other officer of the company, such director, manager, secretary or other officer shall also, be deemed to be guilty of that offence and shall be liable to be proceeded against and punished accordingly.

Explanation – For the purpose of this section -(a) “company” means anybody corporate and includes a firm or other association of individuals; and (b) “director”, in relation to a firm, means a partner in the firm.

59. Previous sanction for prosecution -No prosecution for offences punishable under sections 55 and 56 shall be instituted except with the previous sanction of the Central Government or the State Government, as the case may be, or of any officer authorised in this behalf, by general or special order, by such Government.

60. Cognizance of offences – No Court shall take cognizance of an offence under this Act, except on a complaint made by –(a) the National Authority, the State Authority, the Central Government, the State Government, the District Authority or any other authority or officer authorised in this behalf by that Authority or Government, as the case may be; or (b) any person who has given notice of not less than thirty days in the manner prescribed, of the alleged offence and his intention to make a complaint to the National Authority, the State Authority, the Central Government, the State Government, the District Authority or any other authority or officer authorised as aforesaid.

II. Section 188 in The Indian Penal Code

188. Disobedience to order duly promulgated by public servant –Whoever, knowing that, by an order promulgated by a public servant lawfully empowered to promulgate such order, he is directed to abstain from a certain act, or to take certain order with certain property in his possession or under his management, disobeys such direction, shall, if such disobedience causes or tends to cause obstruction, annoyance or injury, or risk of obstruction, annoyance or injury to any person lawfully employed, be punished with simple imprisonment for a term which may extend to one month or with fine which may extend to two hundred rupees, or with both and if such disobedience causes or trends to cause danger to human life, health or safety, or causes or tends to cause a riot or affray shall be punished with imprisonment of either description for a term which may extend to six months, or with fine which may extend to one thousand rupees, or with both.

Explanation –It is not necessary that the offender should intend to produce harm or contemplate his disobedience as likely to produce harm. It is sufficient that he knows of the order which he disobeys, and that his disobedience produces or is likely to produce harm.

Illustration-An order is promulgated by a public servant lawfully empowered to promulgate such order, directing that a religious shall not pass down a certain street. A knowingly disobeys the order, and thereby causes danger of riot. A has committed the offence defined in this section.

**NILAM SAWHNEY,
CHIEF SECRETARY TO GOVERNMENT**

No. 40-3/2020-DM-I(A)
Government of India
Ministry of Home Affairs

North Block, New Delhi-110001

Dated 24th March, 2020

ORDER

Whereas, the National Disaster Management Authority (NDMA), is satisfied that the country is threatened with the spread of COVID-19 epidemic, which has already been declared as a pandemic by the World Health Organisation, and has considered it necessary to take effective measures to prevent its spread across the country and that there is a need for consistency in the application and implementation of various measures across the country while ensuring maintenance of essential services and supplies, including health infrastructure;

Whereas in exercise of the powers under section 6(2)(i) of the Disaster Management Act, 2005, the National Disaster Management Authority (NDMA), has issued an Order no. 1-29/2020-PP (Pt.II) dated 24.03.2020 (Copy enclosed) directing the Ministries/ Departments of Government of India, State/Union Territory Governments and State/ Union Territory Authorities to take effective measures so as to prevent the spread of COVID-19 in the country;

Whereas under directions of the aforesaid Order of NDMA, and in exercise of the powers, conferred under Section 10(2)(I) of the Disaster Management Act, the undersigned, in his capacity as Chairperson, National Executive Committee, hereby issues guidelines, as per the Annexure, to Ministries/ Departments of Government of India, State/Union Territory Governments and State/ Union Territory Authorities with the directions for their strict implementation. This Order shall remain in force, in all parts of the country for a period of 21 days with effect from 25.03.2020.


24/3/2020
Home Secretary

To

- 1. The Secretaries of Ministries/ Departments of Government of India**
- 2. The Chief Secretaries/Administrators of States/Union Territories**
(As per list attached)

Copy to:

- i. All members of the National Executive Committee.
- ii. Member Secretary, National Disaster Management Authority.

TRUE COPY
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Annexure to Ministry of Home Affairs Order No .40-3/2020-D dated ()24.03.2020

Guidelines on the measures to be taken by Ministries/ Departments of Government of India, State/Union Territory Governments and State/ Union Territory Authorities for containment of COVID-19 Epidemic in the Country.

1. Offices of the Government of India, its Autonomous/ Subordinate Offices and Public Corporations shall remain closed.

Exceptions:

Defence, central armed police forces, treasury, public utilities (including petroleum, CNG, LPG, PNG), disaster management, power generation and transmission units, post offices, National Informatics Centre, Early Warning Agencies

2. Offices of the State/ Union Territory Governments, their Autonomous Bodies, Corporations, etc. shall remain closed.

Exceptions:

- a. Police, home guards, civil defence, fire and emergency services, disaster management, and prisons.
- b. District administration and Treasury
- c. Electricity, water, sanitation
- d. Municipal bodies—Only staff required for essential services like sanitation, personnel related to water supply etc

The above offices (Sl. No 1 & 2) should work with minimum number of employees. All other offices may continue to work-from-home only.

3. Hospitals and all related medical establishments, including their manufacturing and distribution units, both in public and private sector, such as dispensaries, chemist and medical equipment shops, laboratories, clinics, nursing homes, ambulance etc. will continue to remain functional. The transportation for all medical personnel, nurses, para-medical staff, other hospital support services be permitted.

4. Commercial and private establishments shall be closed down.

Exceptions:

- a. Shops, including ration shops (under PDS), dealing with food, groceries, fruits and vegetables, dairy and milk booths, meat and fish, animal fodder. However, district authorities may encourage and facilitate home delivery to minimize the movement of individuals outside their homes.
- b. Banks, insurance offices, and ATMs.
- c. Print and electronic media
- d. Telecommunications, internet services, broadcasting and cable services. IT and IT enabled Services only (for essential services) and as far as possible to work from home.
- e. Delivery of all essential goods including food, pharmaceuticals, medical equipment through E-commerce

- f. Petrol pumps, LPG, Petroleum and gas retail and storage outlets.
- g. Power generation, transmission and distribution units and services.
- h. Capital and debt market services as notified by the Securities and Exchange Board of India
- i. Cold storage and warehousing services.
- j. Private security services

All other establishments may work-from-home only.

5. Industrial Establishments will remain closed.

Exceptions:

- a. Manufacturing units of essential commodities.
- b. Production units, which require continuous process, after obtaining required permission from the State Government

6. All transport services – air, rail, roadways – will remain suspended.

Exceptions:

- a. Transportation for essential goods only.
- b. Fire, law and order and emergency services.

7. Hospitality Services to remain suspended

Exceptions:

- a. Hotels, homestays, lodges and motels, which are accommodating tourists and persons stranded due to lockdown, medical and emergency staff, air and sea crew.
- b. Establishments used/ earmarked for quarantine facilities.

8. All educational, training, research, coaching institutions etc. shall remain closed.

9. All places of worship shall be closed for public. No religious congregations will be permitted, without any exception.

10. All social/ political/ sports/ entertainment/ academic/ cultural/ religious functions / gatherings shall be barred.

11. In case of funerals, congregation of not more than twenty persons will be permitted.

12. All persons who have arrived into India after 15.02.2020, and all such persons who have been directed by health care personnel to remain under strict home/ institutional quarantine for a period as decided by local Health Authorities, failing which they will be liable to legal action under Sec. 188 of the IPC.

13. Wherever exceptions to above containment measures have been allowed, the organisations/employers must ensure necessary precautions against COVID-19

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virus, as well as social distance measures, as advised by the Health Department from time to time.

14. In order to implement these containment measures, the District Magistrate will deploy Executive Magistrates as Incident Commanders in the respective local jurisdictions. The Incident Commander will be responsible for the overall implementation of these measures in their respective jurisdictions. All other line department officials in the specified area will work under the directions of such incident commander. The Incident Commander will issue passes for enabling essential movements as explained.
15. All enforcing authorities to note that these strict restrictions fundamentally relate to movement of people, but not to that of essential goods.
16. The Incident Commanders will in particular ensure that all efforts for mobilisation of resources, workers and material for augmentation and expansion of hospital infrastructure shall continue without any hindrance.
17. Any person violating these containment measures will be liable to be proceeded against as per the provisions of Section 51 to 60 of the Disaster Management Act, 2005, besides legal action under Sec. 188 of the IPC (as per Appendix).
18. The above containment measures will remain in force, in all parts of the country, for a period of 21 days with effect from 25.03.2020.


Union Home Secretary

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1. Section 51 to 60 of the Disaster Management Act, 2005

OFFENCES AND PENALTIES

51. Punishment for obstruction, etc.—Whoever, without reasonable cause —

(a) obstructs any officer or employee of the Central Government or the State Government, or a person authorised by the National Authority or State Authority or District Authority in the discharge of his functions under this Act; or

(b) refuses to comply with any direction given by or on behalf of the Central Government or the State Government or the National Executive Committee or the State Executive Committee or the District Authority under this Act,

shall on conviction be punishable with imprisonment for a term which may extend to one year or with fine, or with both, and if such obstruction or refusal to comply with directions results in loss of lives or imminent danger thereof, shall on conviction be punishable with imprisonment for a term which may extend to two years.

52. Punishment for false claim.—Whoever knowingly makes a claim which he knows or has reason to believe to be false for obtaining any relief, assistance, repair, reconstruction or other benefits consequent to disaster from any officer of the Central Government, the State Government, the National Authority, the State Authority or the District Authority, shall, on conviction be punishable with imprisonment for a term which may extend to two years, and also with fine.

53. Punishment for misappropriation of money or materials, etc.—Whoever, being entrusted with any money or materials, or otherwise being, in custody of, or dominion over, any money or goods, meant for providing relief in any threatening disaster situation or disaster, misappropriates or appropriates for his own use or disposes of such money or materials or any part thereof or wilfully compels any other person so to do, shall on conviction be punishable with imprisonment for a term which may extend to two years, and also with fine.

54. Punishment for false warning.—Whoever makes or circulates a false alarm or warning as to disaster or its severity or magnitude, leading to panic, shall on conviction, be punishable with imprisonment which may extend to one year or with fine.

55. Offences by Departments of the Government.—(1) Where an offence under this Act has been committed by any Department of the Government, the head of the Department shall be deemed to be guilty of the offence and shall be liable to be proceeded against and punished accordingly unless he proves that the offence was committed without his knowledge or that he exercised all due diligence to prevent the commission of such offence.

(2) Notwithstanding anything contained in sub-section (1), where an offence under this Act has been committed by a Department of the Government and it is proved that the

offence has been committed with the consent or connivance of, or is attributable to any neglect on the part of, any officer, other than the head of the Department, such officer shall be deemed to be guilty of that offence and shall be liable to be proceeded against and punished accordingly.

56. Failure of officer in duty or his connivance at the contravention of the provisions of this Act.—Any officer, on whom any duty has been imposed by or under this Act and who ceases or refuses to perform or withdraws himself from the duties of his office shall, unless he has obtained the express written permission of his official superior or has other lawful excuse for so doing, be punishable with imprisonment for a term which may extend to one year or with fine.

57. Penalty for contravention of any order regarding requisitioning.—If any person contravenes any order made under section 65, he shall be punishable with imprisonment for a term which may extend to one year or with fine or with both.

58. Offence by companies.—(1) Where an offence under this Act has been committed by a company or body corporate, every person who at the time the offence was committed, was in charge of, and was responsible to, the company, for the conduct of the business of the company, as well as the company, shall be deemed to be guilty of the contravention and shall be liable to be proceeded against and punished accordingly: Provided that nothing in this sub-section shall render any such person liable to any punishment provided in this Act, if he proves that the offence was committed without his knowledge or that he exercised due diligence to prevent the commission of such offence. (2) Notwithstanding anything contained in sub-section (1), where an offence under this Act has been committed by a company, and it is proved that the offence was committed with the consent or connivance of or is attributable to any neglect on the part of any director, manager, secretary or other officer of the company, such director, manager, secretary or other officer shall also, be deemed to be guilty of that offence and shall be liable to be proceeded against and punished accordingly.

Explanation.—For the purpose of this section— (a) “company” means any body corporate and includes a firm or other association of individuals; and (b) “director”, in relation to a firm, means a partner in the firm.

59. Previous sanction for prosecution.—No prosecution for offences punishable under sections 55 and 56 shall be instituted except with the previous sanction of the Central Government or the State Government, as the case may be, or of any officer authorised in this behalf, by general or special order, by such Government.

60. Cognizance of offences.—No court shall take cognizance of an offence under this Act except on a complaint made by— (a) the National Authority, the State Authority, the Central Government, the State Government, the District Authority or any other authority or officer authorised in this behalf by that Authority or Government, as the case may be; or (b) any person who has given notice of not less than thirty days in the manner prescribed, of the alleged offence and his intention to make a complaint to

the National Authority, the State Authority, the Central Government, the State Government, the District Authority or any other authority or officer authorised as aforesaid.

2. Section 188 in The Indian Penal Code

188. Disobedience to order duly promulgated by public servant.—Whoever, knowing that, by an order promulgated by a public servant lawfully empowered to promulgate such order, he is directed to abstain from a certain act, or to take certain order with certain property in his possession or under his management, disobeys such direction, shall, if such disobedience causes or tends to cause obstruction, annoyance or injury, or risk of obstruction, annoyance or injury, to any person lawfully employed, be punished with simple imprisonment for a term which may extend to one month or with fine which may extend to two hundred rupees, or with both; and if such disobedience causes or tends to cause danger to human life, health or safety, or causes or tends to cause a riot or affray, shall be punished with imprisonment of either description for a term which may extend to six months, or with fine which may extend to one thousand rupees, or with both.

Explanation.—It is not necessary that the offender should intend to produce harm, or contemplate his disobedience as likely to produce harm. It is sufficient that he knows of the order which he disobeys, and that his disobedience produces, or is likely to produce, harm.

Illustration

An order is promulgated by a public servant lawfully empowered to promulgate such order, directing that a religious procession shall not pass down a certain street. A knowingly disobeys the order, and thereby causes danger of riot. A has committed the offence defined in this section.

LG Polymers India Pvt. Ltd.

Regd. Office & Works : R.R. Venkatapuram, Visakhapatnam - 530 029, India
CORPORATE IDENTITY NUMBER (CIN) : U25203AP1996PTC025917ISO 9001:2015 &
ISO 14001:2015
BUREAU VERITAS
Certification

Visakhapatnam	91-891-2520455 - 458	Fax : 91-891-2520528
Mumbai	91-22-61085300 - 332	Fax : 91 - 22-61085344
Gurgaon	91-0124-4692700 -11,	Fax : 91-0124-4692701
Kolkatta	91-33-25797977 & 78	
Chennai	91-44-26650201	Fax : 91-44-43870203
Vijayawada	91-9849170565	
Pune	91-020-66487600	

Ref: LGPI/03/2020
Date: 28.03.2020The Joint Collector
Collector Office
Visakhapatnam

Respected Sir,

Sub: Request Emergency Duty Identity Cards for the skeletal staff - RegRef: 1) Government of AP G.O.Rt.No. dt. 22.03.2020
2) LGPI letter to District Collector dt.23.03.2020

We, LG Polymers India Pvt. Limited, situated in RR Venkatapuram, Visakhapatnam is a South Korean MNC Company. We manufacture Polystyrene & expandable polystyrene using the main raw material Styrene Monomer (SM) which is imported from South East Asian countries. Ours is a petrochemical plant classified under MAH category, continuous polymerization of SM. We employ about 500 employees both permanent & contract workers.

Based on District Collector orders dt. 23rd March,20 we have stopped / shutdown our continuous process plants on 23rd / 24th March. However we have to closely monitor the raw materials SM, Pentane (hazardous and classified as Class A & B petroleum products) stored in the tank farm. Hence we have deployed skeletal manpower 60 persons to monitor the raw material inventories round the clock as the above raw materials are to be maintained in refrigerated condition (as per MSDS - Material Safety Data Sheet).

Hence, we humbly request your good offices to **grant Emergency Duty permission passes** to deploy 60 skeletal staff for monitoring the raw materials. We humbly request you to consider our request in view of the raw material safety.

Thanking you,

Your faithfully,
For LG Polymers India Pvt. Limited
P.P.C. Mohan Rao
Director (Operations)

CC TO: GM - Industries

Date: 01.04.2020

LOCKDOWN INSTRUCTIONS-PRODUCTION TEAM :

In view of plant shutdown due to lock down for COVID-19 issue, the following guidelines to be followed. These instructions will be in addition to our routine standard operating procedures for plant shutdowns.

General Jobs after shutdown (All Plants):

- All the left over styrene in pipelines / process vessels must be drained & collected into drums.
- Lines / Process vessels to be purged with Air completely and ensured that there is no left over Styrene in the lines.
- QVF Pots, Duplex Filters, Bag Filters, Mesh Filters, Strainers, Collection tank & Seal pots etc., must be drained completely.
- Please ensure that all Control Valves are drained off Styrene (Instrumentation).
- Left over Peroxide (TBEC) carbouys are to be handed over to Stores and ensure that it is stocked in cold storage.
- Ensure that all the local push buttons of the equipment's are locked.
- Ensure that minimum stocks of material (FG, RM, and Packing material) are at the site. (to be registered)
- Fired Heater FO Day tank levels to be maintained on lower side i.e say below 30%.
- Cooling Tower sump to be drained off completely.
- All process plant employees' should monitor tank farm and product godowns closely and also monitor storage temperatures in their respective control rooms.
- Make plant surveillance rounds covering - Tank Farm, HCl Storage, Heater area, ETP, Boilers, DCS Control Rooms & MCC & inverter Rooms, Scrap yards.
- Monitor tank Farm area parameters in DCS & inform in case of any abnormality to EDO/NDO.
- Monitor Peroxide storage temperature and ensure AC is running all the time.

GPPS Plant:

- All process valves in GPPS plant to be checked for free operability. (Open / Close once in a week)
- Make sure all process lines/condensers and equipment are free of Styrene. Make sure to drain from low point drains.
- Drained Styrene drums to be monitored for any temperature build-up/signs of polymer growth.
- Monitor and log SMH tank farm temperatures in log books

HIPS Plant:

- Make HIPS tank farm surveillance rounds.
- Closely monitor Monomer tank temperatures and Check and record Tanks temperature and levels. Ensure circulation of Monomer tanks with process pumps.
- Offer samples to QA for analysis of Polymer and Inhibitor testing.

- All process and tank farm valves are to be checked for free operability (Open / Close once in a week)
- Drained Styrene drums to be monitored closely for any temperature build-up / signs of polymer growth.

EPS Plant:

- All Styrene Tanks and pipeline valves in EPS plant are to be checked for free operability. (Open / Close).
- Operate Aeration tank air blowers for 2 hrs per shift for ensuring dissolved Oxygen to bacteria in Aeration tank. Add nutrients regularly and recycle sludge as required
- Closely monitor EPS godown temperatures closely and ensure operation of refrigeration.
- Drained Styrene drums to be monitored closely for any temperature build-up / signs of polymer growth.

Styrene Monomer Handling Area:

- Ensure daily running of Refrigeration unit to maintain SM temperatures below 25 deg C.
- Make sure to close all isolation valves of tanks after stopping unloading/refrigeration activities.
- Check and Record Tanks temperatures and levels. SM tank parameters to be closely monitored in DCS.
- All Styrene Tanks and pipeline valves are to be checked for free operability. (Open /Close).
- Offer SM samples to QA for analysis of polymer and inhibitor testing.

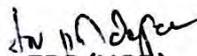
General:

- Lock down communication what's app group created and added all key production team members.
- All-important communications required should be done through this WhatsApp group.
- All necessary precautions to be taken in view of Covid-19.
- Make rounds in all finished goods / raw material godowns / LPG storage and inform in case of any abnormality to special safety officer in shifts.
- All members in the shift are will be fire squad members without the need for any special schedule. (One senior person shall be Fire squad officer).
- Ensure fire water tank levels are full always and all fire hydrant pumps are in Auto mode.


 TEAM LEADER (PROD)


 GPPS (HOD)


 HIPS (HOD)


 EPS (HOD)


 SMH IN-CHARGE

APPENDIX - 9

 LG Chem LG Polymers India Pvt. Ltd.	INSPECTION REPORT OF INCOMING RAW MATERIALS AND CHEMICALS	FORMAT : LGPI/QAD/816FFS/001 Date: 22.04.2020	
Offer particulars:			
Offered by (plant)	SMH		
Date of offer	21.04.2020		
Material	STYRENE MONOMER		
Batch number	-----		
Consignment	HANWHA		
Truck / tanker No.	DH FEALTY		
Invoice No. & Date	-----		
Quantity	6242.471 MT.		
Characteristics	Specifications	Measured / tested value	Conforming(C) / non-conformed(NC)
Purity by GC	99.7 %Min	99.9819	Confirmed
TBC	10-20 ppm	15	Confirmed
Polymer	10 ppm Max	02	Confirmed
Colour	20 HU Max	15	Confirmed
Aldehydes as [Benzaldehyde]	0.01 (wt%Max)	0.0030	Confirmed
Peroxides [as hydrogen peroxide]	0.01 (wt%Max)	0.0020	Confirmed
Result	√ <input type="checkbox"/> Conforming <input checked="" type="checkbox"/> Non-Conforming		
Signatures	R.Ramesh Analysed / Verified by	BR Checked by	 Approved by
<u>Disposition</u> : (If Non-conforming) (tick appropriate box)			
<input type="checkbox"/> → Accept with deviation (Explain reasons & follow – up actions on process if any)			
<input type="checkbox"/> → Reject			
Signature: HOD (respective plant)			Date:

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1201	07-05-2020	02:54:25	O-AT-141B_AL	M6 TANK GAS DET_B ALARM	ALM					
1201	07-05-2020	02:54:30	O-AT-141A_AL	M6 TANK GAS DET_A ALARM	ALM					
1601	07-05-2020	02:54:34	HTRRESET	HOOTER RESET	PV	=	1	old=	0	[OFFUSER@HIS0162
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1201	07-05-2020	02:55:33	O-AT-140D_AL	M5 TANK GAS DET_D ALARM	ALM					
1601	07-05-2020	02:55:42	HTRRESET	HOOTER RESET	PV	=	1	old=	0	[OFFUSER@HIS0162
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1101	07-05-2020	02:57:59	O-VOC-143	STY UNLOADING AREA VOC	PV	=	3 PPM	IOP		
1201	07-05-2020	02:58:04	O-AT-140B_AL	M5 TANK GAS DET_B ALARM	ALM					
1201	07-05-2020	02:58:06	O-AT-341A_AL	LPG GODOWN GAS DET ALARM	ALM					
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1206	07-05-2020	04:32:00	O-AT-240A_AL	PEN TANK GAS DET_A ALARM	NR					
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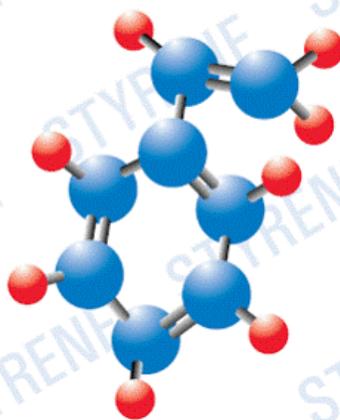
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1201 07-05-2020 05:28:15 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
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1206 07-05-2020 05:28:47 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1201 07-05-2020 05:28:52 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1201 07-05-2020 05:29:13 O-AT-240C_AL PEN TANK GAS DET_C ALARM ALM
1206 07-05-2020 05:30:46 O-AT-240C_AL PEN TANK GAS DET_C ALARM NR
1206 07-05-2020 05:32:15 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1201 07-05-2020 05:32:25 O-AT-142D_AL 1221ATNK GAS DET_D ALARM ALM
1201 07-05-2020 05:32:41 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1206 07-05-2020 05:32:51 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1206 07-05-2020 05:33:23 O-AT-140C_AL M5 TANK GAS DET_C ALARM NR
1201 07-05-2020 05:33:30 O-AT-241D_AL PEN UNLD GAS DET_B ALARM ALM
1201 07-05-2020 05:34:20 O-AT-142C_AL 1221ATNK GAS DET_C ALARM ALM
1201 07-05-2020 05:35:01 O-AT-240A_AL PEN TANK GAS DET_A ALARM ALM
1201 07-05-2020 05:35:07 O-AT-240D_AL PEN TANK GAS DET_D ALARM ALM
1201 07-05-2020 05:35:17 O-AT-240C_AL PEN TANK GAS DET_C ALARM ALM
1206 07-05-2020 05:37:53 O-AT-240D_AL PEN TANK GAS DET_D ALARM NR
1206 07-05-2020 05:38:09 O-AT-240A_AL PEN TANK GAS DET_A ALARM NR
1201 07-05-2020 05:38:35 O-AT-240A_AL PEN TANK GAS DET_A ALARM ALM
1201 07-05-2020 05:38:45 O-AT-240D_AL PEN TANK GAS DET_D ALARM ALM
1201 07-05-2020 05:38:59 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1201 07-05-2020 05:39:53 O-AT-240B_AL PEN TANK GAS DET_B ALARM ALM
1206 07-05-2020 05:40:55 O-AT-240C_AL PEN TANK GAS DET_C ALARM NR
1206 07-05-2020 05:40:55 O-AT-240D_AL PEN TANK GAS DET_D ALARM NR
1206 07-05-2020 05:41:22 O-AT-240B_AL PEN TANK GAS DET_B ALARM NR
1206 07-05-2020 05:41:48 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1201 07-05-2020 05:41:53 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1206 07-05-2020 05:41:53 O-AT-240A_AL PEN TANK GAS DET_A ALARM NR
1206 07-05-2020 05:42:29 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1201 07-05-2020 05:42:34 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1201 07-05-2020 05:42:34 O-AT-240A_AL PEN TANK GAS DET_A ALARM ALM
1206 07-05-2020 05:44:08 O-AT-240A_AL PEN TANK GAS DET_A ALARM NR
1206 07-05-2020 05:44:47 O-AT-241D_AL PEN UNLD GAS DET_B ALARM NR
1206 07-05-2020 05:45:16 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1201 07-05-2020 05:45:26 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1201 07-05-2020 05:46:05 O-AT-241D_AL PEN UNLD GAS DET_B ALARM ALM
1206 07-05-2020 05:47:23 O-AT-241D_AL PEN UNLD GAS DET_B ALARM NR
1206 07-05-2020 05:48:39 O-AT-142C_AL 1221ATNK GAS DET_C ALARM NR
1206 07-05-2020 05:48:49 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1201 07-05-2020 05:49:10 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1206 07-05-2020 05:49:52 O-AT-142D_AL 1221ATNK GAS DET_D ALARM NR
1601 07-05-2020 05:49:56 HTRRESET HOOTER RESET PV = 1 old= 0 [ OFFUSER@HIS0162 ]
1201 07-05-2020 05:50:02 O-AT-142D_AL 1221ATNK GAS DET_D ALARM ALM
1601 07-05-2020 05:50:14 HTRRESET HOOTER RESET PV = 1 old= 0 [ OFFUSER@HIS0162 ]
1601 07-05-2020 05:50:36 G-FIC-101_BS BSET= 25000.0 KG old= 1.0 [ OFFUSER@HIS0162 ]
1601 07-05-2020 05:50:46 STYRENE STYRENE BATCH ST PV = 1 old= 0 [ OFFUSER@HIS0162 ]
1401 07-05-2020 05:50:46 G-SOV-101 AUT
1206 07-05-2020 05:50:48 G-SOV-101OP SOV-101 OPEN NR
1206 07-05-2020 05:50:48 G-SOV-101CL SOV-101 CLOSE NR
1601 07-05-2020 05:50:55 G-FIC-101_BS SUM = 0.0 KG old= 19113.7 [ OFFUSER@HIS0162 ]
1102 07-05-2020 05:50:55 G-FIC-101_BS PV = 0.3 KG LEAK Recover
1106 07-05-2020 05:50:55 G-FIC-101_BS NR
1401 07-05-2020 05:50:59 G-SOV-101 MAN
1206 07-05-2020 05:53:10 O-AT-142D_AL 1221ATNK GAS DET_D ALARM NR
1206 07-05-2020 05:54:17 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1201 07-05-2020 05:54:22 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1206 07-05-2020 05:54:38 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1201 07-05-2020 05:54:48 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1206 07-05-2020 05:56:22 O-AT-140A_AL M5 TANK GAS DET_A ALARM NR
1201 07-05-2020 05:56:27 O-AT-140A_AL M5 TANK GAS DET_A ALARM ALM
1206 07-05-2020 05:56:43 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1201 07-05-2020 05:56:48 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1206 07-05-2020 05:57:14 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1201 07-05-2020 05:57:19 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1206 07-05-2020 05:57:51 O-AT-140D_AL M5 TANK GAS DET_D ALARM NR
1201 07-05-2020 05:57:59 O-AT-140D_AL M5 TANK GAS DET_D ALARM ALM
1803 07-05-2020 05:59:59 FCS0101 FRQ0001 not

```

Material Stocks Between 2020.05.01 and 2020.05.31

Matl	Material Description	Quantities BUn	Values Crpy
G311 PAOETC0005 ANTI-OXIDANT (EUNOX - 76)			
Stock/Value on 2020.05.01		2,739.850 KG	880,396.00 INR
Total/Val. of Receipts		0.000 KG	0.00 INR
Total/Value of Issues		489.850- KG	157,448.50- INR
Stock/Value on 2020.05.31		2,250.000 KG	722,947.50 INR
G311 PATETC0024 PARA TERTIARY BUTYL CATECHOL (PTBC)			
Stock/Value on 2020.05.01		0.000 KG	0.00 INR
Total/Val. of Receipts		1,500.000 KG	916,755.00 INR
Total/Value of Issues		515.000- KG	314,752.55- INR
Stock/Value on 2020.05.31		985.000 KG	602,002.45 INR
G311 PCKTDM0001 TERTI DODECYL MERCAPTAN			
Stock/Value on 2020.05.01		2,487.160 KG	685,834.37 INR
Total/Val. of Receipts		2,144.640 KG	594,441.47 INR
Total/Value of Issues		699.960- KG	193,475.94- INR
Stock/Value on 2020.05.31		3,931.840 KG	1,086,799.90 INR
G311 PRADDC0001 NORMAL DODECYL MERCAPTAN			
Stock/Value on 2020.05.01		1,059.000 KG	430,218.75 INR
Total/Val. of Receipts		2,040.000 KG	828,750.00 INR
Total/Value of Issues		1,059.000- KG	430,218.75- INR
Stock/Value on 2020.05.31		2,040.000 KG	828,750.00 INR

Safe Handling and Storage of Styrene Monomer



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PART 3**STYRENE MONOMER STORAGE**

The prevention of polymer build-up is the primary concern in the storage of styrene monomer. Prevention of color formation is also important, but this is normally caused by contamination such as rust. Low temperatures, maintaining proper inhibitor and dissolved oxygen levels, correct construction materials, and good housekeeping are all important factors in maintaining a long shelf life.

Contact AmSty (+1-844-512-1212) with questions regarding Styrene Monomer inhibition and inhibitor testing.

Polymerization in Storage

Styrene polymerizes slowly at normal ambient temperatures but very rapidly at elevated temperatures. Styrene polymerization is initiated by heat, lack of inhibitor and dissolved oxygen, and contact with peroxides and other free-radical initiators, ionic initiators, and redox initiators. Polymerization can take place in storage as well as under more controlled conditions. The polymerization process is exothermic, evolving 288 BTU/lb (17.8 kcal/g-mole). If this evolved heat cannot be dissipated rapidly enough, the temperature of the monomer will rise, increasing the rate of polymerization and, with it, the rate of evolution of heat. The temperature may rise to the point where the reaction becomes very rapid and self-sustaining (a runaway polymerization). Normally, temperatures above 149 °F (65 °C) are needed to initiate runaway polymerizations.

During a runaway polymerization, the temperature will reach and exceed the boiling point of styrene. The vapor may erupt violently from the tank vents or, if the vents are plugged or too small, it can create enough pressure to rupture the tank. As the liquid polymerizes and becomes more viscous, vapor bubbles may become trapped, expanding the liquid and causing spills or rupture of the tank.

The important point is that polymerization may occur spontaneously in storage tanks. Depending on the quantity of material being stored, serious consequences may result.

Prevention of Polymerization

Polymerization during storage may be prevented by close attention to monomer temperature, inhibitor level, polymer content and oxygen content. Determinations of inhibitor content, oxygen level in the vapor space, polymer content, and monomer temperature should be made on a routine basis. Styrene-containing vessels should be protected from external sources of heat. Running pumps against closed valves (dead-heading) should be avoided. Care should be taken that vents, valves, pressure-relief devices, gauges, and controls do not become plugged with polymer.

Handling Runaway Polymerizations

The action to take will depend on how far the runaway has proceeded. The beginning of a runaway polymerization may be identified by an increase in monomer temperature (particularly if monomer temperature exceeds ambient or rises more than 3 °F (1.6 °C) in one day). The higher the temperature, the further the runaway has progressed and the more difficult to stop. Decisions concerning what actions to take must be made on-site, but AmSty may be contacted for guidance at +1-844-512-1212. The following suggestions are listed approximately in the order recommended for halting a runaway polymerization and dealing with an advanced runaway:

1. Add up to 0.5% TBC and aerate. Aeration can be accomplished by bubbling in air, or stirring the product while exposed to air. Facilities storing and handling styrene

monomer should have TBC inhibitor on hand in case of emergency.

2. Reduce temperature of tank with water spray. If the tank is insulated, the insulation should be removed as quickly as possible and prior to spraying with water. Use ice, if feasible, but not in the product directly, as it will tend to remove the TBC. If placed in the product, ice should be in a sealed metal container.
3. Keep vessel vented.
4. Dilute with ethylbenzene or toluene, if tank is not venting and product temperature is below 231 °F (110 °C), to retard polymerization and reduce viscosity.
5. If possible, remove product from tank before it solidifies, to save the tank. Use drums, diked area, or float on water in a pond or confined area.

TBC Inhibitor Test Comparison Card

The AmSty TBC Inhibitor Test Comparison Card can be used to estimate inhibitor levels under laboratory and field conditions. This Test Comparison Card may be obtained by contacting your Sales representative or by mailing a request to:

Americas Styrenics LLC
24 Waterway Avenue
Suite 1200
The Woodlands, TX 77380

Note: TBC Specification analysis must be performed using ASTM Method D4590.

Inhibition

TBC (4-tert-Butylcatechol) is customarily added to styrene to prevent polymer formation and oxidative degradation during shipment and subsequent storage.

Inhibitors prevent polymerization in two ways: (1) they can react with and deactivate the free radical in a growing chain, and (2) they can act

as an antioxidant and prevent polymerization by reacting with oxidation products in the monomer. **Note:** Sufficient oxygen must be present for inhibition. In the absence of oxygen, polymerization will proceed as if no inhibitor were present.

The TBC level should be checked at regular intervals (See Table 2B of this section). Additional inhibitor should be added to maintain a safe level.

The time required for TBC concentrations to fall to a dangerously low level varies greatly because of different storage and handling conditions. The depletion rates in actual storage may be appreciably faster or slower depending on the set of environmental conditions. Factors which affect depletion of TBC are heat, water and air; with heat being the most important.

If the inhibitor has been depleted and polymerization has begun, inhibitor should be added immediately. If unstable monomer is not treated promptly, it may become unsalvageable.

Additional inhibitor should be added when inhibitor levels drop below 10 ppm to maintain adequate inhibition. Normal levels are 10-15 ppm, but some customers may require up to 100 ppm because of unique storage conditions or process requirements. After addition, the storage tank should be recirculated until inhibitor is uniformly mixed and testing shows that target levels have been achieved. The tank should also be aerated to provide the proper amount of dissolved oxygen. Refer to Table 3A or 3B to determine the proper amount of inhibitor to add.

The relatively small quantities of TBC required to raise the inhibitor level in stored monomer can most easily be added by using an 85 % TBC / 15 % Methanol blend or a concentrated stock solution in the monomer or other solvent. Concentrated stock solution has an indefinite storage life when stored in the dark at normal ambient temperatures.

A TBC concentrate for use in increasing the inhibitor level in styrene monomer can be prepared by dissolving 704 grams of pure TBC in 1 gal of styrene monomer (186 gram/liter).

At this concentration, 1 cc of the concentrate will raise the level of inhibitor 1 ppm in a drum of styrene having a net weight of 410 lb (186 kg). Table 3A lists the amount of concentrate required to increase the inhibitor level of bulk quantities by 10 ppm.

Styrene vapors in storage tanks are not inhibited and can polymerize on roofs of storage tanks and around vents. Vapor space inhibitors are available but are not viewed as being adequately effective.

Table 1

Effect of Inhibitor and Oxygen on the Shelf Life of Styrene at Various Temperatures

Monomer Temperature	12 ppm TBC		50 ppm TBC
	Saturated with Air	Less than 3 ppm O ₂	Saturated with Air
60 °F (15.6 °C)	6 months	10 to 15 days	1 year
85 °F (29.4 °C)	3 months	4 to 5 days	6 months
110 °F (43.3 °C)	8 to 12 days	Less than 24 hours	Less than 30 days

Table 2A

Suggested Monitoring Schedule for Styrene Bulk Storage

Monomer Temperature	Daily
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Table 2B

Suggested Testing Schedule for Styrene Bulk Storage

Monomer Temperature	Frequency	Key Properties	
80 °F (26.7 °C) or Higher	Twice a week	Polymer	ASTM D2121
		Inhibitor	ASTM D4590
70 – 79 °F (21.1 – 26.1 °C)	Weekly	Color	ASTM D5386
		Aldehydes	ASTM D2119
Below 70 °F (21.1 °C)	Bi-weekly	Peroxides	ASTM D2340
		Appearance	ASTM D4176

3. Passing the styrene over silica gel or alumina. This method has the disadvantage of removing the TBC inhibitor, which must be replaced. Acidic or highly-activated alumina may cause the styrene to polymerize. Verify the applicability of the material selected by using a small bench scale test.

Particulate Matter

Styrene should be free of particulate matter when it is polymerized. Although some particulate matter in styrene originates from outside contamination via the receiving-transfer system, it is also formed by the reaction of concentrated TBC solutions with iron. This may occur in lines which have contained styrene but have been blown dry.

Particulate matter in styrene may be avoided by:

1. Paying careful attention to cleanliness.
2. Properly coating the inside of tanks and transfer lines which may contain high concentrations of TBC or which may be blown dry after carrying TBC-inhibited styrene. Stainless steel vessels and lines are also recommended.
3. Filtering styrene to remove particulate matter before storage, shipment, or use.

Drums

Drums of styrene monomer should not be permitted to stand in the sun for more than a short period of time. As soon as possible after being received, drums should be moved to a cool, shaded area. In hot weather, drums can be cooled with a water spray. It is also advisable that inventories be kept to a minimum during summer months and that monomer is stored no longer than necessary. Adding additional TBC during hot weather is also recommended. Styrene should be stored in white drums that reflect sunlight as a means to control temperature.

Tanks

In designing bulk storage facilities, certain basic factors must be considered. Styrene monomer can be stored for relatively long periods of time if simple, but carefully prescribed conditions are met. In addition to the usual precautions taken with flammable liquids against fire and explosion hazards, precautions must be taken against conditions that will promote the formation of polymer and oxidation products. To accomplish this, the design and construction of a satisfactory bulk storage system for styrene requires careful consideration to eliminate excessive temperatures and to prevent contamination with polymer from infrequently used lines and other equipment. Figures 1 and 2 show two different types of storage installations.

A self-supporting type dome roof is recommended for vertical storage tanks. This type of construction simplifies the installation of linings and permits rapid drainage of uninhibited condensed vapors back into the liquid monomer, thus reducing the polymer and stalactite problem. Roof and sidewall openings above the normal liquid levels in the tank should be of large diameter and the number kept to a minimum.

Large diameter openings are easily lined and can also be used for dual-service purposes where feasible.

Insulation and refrigeration of storage tanks is recommended for environments where temperatures exceed 75 °F (23.9 °C) for long periods of time.

Most consuming locations insulate storage tanks to dampen the effect of high daytime temperatures but do not install refrigeration due to cost.

Lined carbon steel tanks are generally used for the bulk storage of styrene monomer. Vertical storage tanks are commonly used for large volume storage. Horizontal tanks are equally satisfactory for bulk storage, but are generally used for smaller installations. The inlet and outlet lines for these tanks are normally located near the bottom. To facilitate mixing where external refrigeration is employed, it is recommended that either the outlet line or the



**Safe Handling and Storage of
Styrene Monomer**

or aluminum foil liner. If new bottles are used, first rinse them thoroughly with acetone or methanol and then dry in a hot-air oven. Hold in a desiccator while cooling to ambient temperature. Protect them from dirt or moisture by enclosure in a polyethylene bag. Rinse used bottles very thoroughly with water, detergents, and solvents and then treat as new bottles.

The sampling system should be bonded to the tank manway (e.g. by resting the chain on the lip of the manway) prior to sampling.

REFERENCE DOCUMENTS:

ASTM D3437: Practice for Sampling and Handling Cyclic Compounds

ASTM E300: Practice for Sampling Industrial Chemicals

ANSI Z 288.1: Flammable and Combustible Liquids Code

API RP 500A: Classification of Locations for Electrical Installations in Petroleum Refineries

OSHA Regulations, 29 CFR, Paragraphs 1910.1000 and 190.2000

U.S. DOT Regulations, 49 CFR, Transportation Subchapters B and C, Parts 171-179

Chevron Phillips Chemical Company LP
MSDS 100000068536

SAMPLING DEVICES

Quality control within the process industry is of prime importance. This demands stringent checks, not only of the finished product, but also throughout the various stages of production, distribution and use.

The need for representative samples plays a critical role in ensuring product quality. Yet sampling directly often includes the risks of exposure to the operator as well as contamination and pollution to the environment. Use of a system such as the DOPAK[®] sampling method for process samples and HERMetric[®] Sampler for tank samples significantly reduces such risks. Texas Sampling Inc. also markets closed loop sampling systems.

STATIC ELECTRICITY AND GROUNDING

Static electricity can cause difficulties such as fires and explosions unless certain precautions are observed. Styrene monomer, has a high volume resistivity, and can pick up and hold a static charge during transfer operations. Key operations which have the potential of generating a flammable atmosphere and/or static charge include tank and container filling, splash filling, tank cleaning, sampling, gauging, switch loading, filtering, mixing/agitation, and vacuum truck operations. To minimize the hazard of static electricity during these operations, bonding and grounding may be necessary but may not by themselves be sufficient. For more information, refer to OSHA Standard 29 CFR 1910.106, "Flammable and Combustible Liquids", National Fire Protection Association (NFPA) 77, "Recommended Practice on Static Electricity" and/or the American Petroleum Institute (API) Recommended Practice 2003, "Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents.

The use of insulating flanges or non-insulating hoses are recommended for marine vessel/shore connections.

Submerged filling is recommended for all flammable liquids. The inlet line should discharge at, or near, the bottom and make electrical contact with the tank to eliminate uncontrolled electrical discharge.

Operators wearing rubber-soled shoes, particularly on certain composition floors made of good insulating materials, may pick up considerable static electricity.

PRODUCT LOADING/UNLOADING REQUIREMENTS

When loading or unloading a vessel or barge:
Refer to current ISGOTT and USCG rules.

When loading or unloading tank cars:

1. Use only clean, oil- and dirt-free, spark-resistant tools and implements.

PART 3

STYRENE MONOMER STORAGE

The prevention of polymer build-up is generally of greatest concern in the storage of styrene monomer. Prevention of color formation is also important, but this is normally caused by contamination such as rust. Low temperatures, maintaining proper inhibitor and dissolved oxygen levels, correct construction materials, and good housekeeping are factors important in maintaining a long shelf life.

POLYMERIZATION IN STORAGE

Styrene polymerizes slowly at normal ambient temperatures but very rapidly at elevated temperatures. Styrene polymerization is initiated by heat, lack of inhibitor and dissolved oxygen, and contact with peroxides and other free-radical initiators, ionic initiators, and redox initiators. Polymerization can take place in storage as well as under more controlled conditions. The polymerization process is exothermic, evolving 288 btu/lb (17.8 kcal/gm-mole). If this evolved heat cannot be dissipated rapidly enough, the temperature of the monomer will rise, increasing the rate of polymerization and, with it, the rate of evolution of heat. The temperature may rise to the point where the reaction becomes very rapid and self-sustaining (a runaway polymerization). Normally temperatures above 65°C (149°F) are needed to initiate runaway polymerizations.

During a runaway polymerization, the temperature will reach and exceed the boiling point of styrene. The vapor may erupt violently from the tank vents or, if the vents are plugged or too small, it can create enough pressure to rupture the tank. As the liquid polymerizes and becomes more viscous, vapor bubbles may become trapped, expanding the liquid and causing spills or rupture of the tank.

The important point is that polymerization may occur spontaneously in storage tanks.

Depending on the quantity of material being stored, serious consequences may result.

PREVENTION OF POLYMERIZATION

Polymerization during storage may be prevented by close attention to monomer temperature, inhibitor level, polymer content and oxygen content. Determinations of inhibitor content, oxygen level in the vapor space, polymer content, and monomer temperature should be made on a routine basis (details are provided in Part 4). Styrene-containing vessels should be protected from external sources of heat. Running pumps against closed valves (dead-heading) should be avoided. Care should be taken that vents, valves, pressure-relief devices, gauges, and controls do not become plugged with polymer. (Requirements for the preceding are discussed in detail in the Styrene Monomer Storage Section of this publication).

HANDLING RUNAWAY POLYMERIZATIONS

The action to take will depend on how far the runaway has proceeded. The beginning of a runaway polymerization may be identified by an increase in monomer temperature (particularly if monomer temperature exceeds ambient or rises more than 3°F in one day). The higher the temperature the further the runaway has progressed and the more difficult to stop. Decisions concerning what actions to take must be made on-site. The following suggestions are listed approximately in the order recommended for halting a runaway polymerization and dealing with an advanced runaway:

1. Add up to 0.5% TBC and aerate. Aeration can be accomplished by bubbling in air, or stirring the product while exposed to air. Facilities storing and handling styrene monomer should have TBC inhibitor on hand in case of emergency. Solutions of

TBC may be obtained by contacting your Chevron Phillips Chemical Company LP representative or through your purchasing agent.

2. Reduce temperature of tank with water spray. If the tank is insulated, the insulation should be removed as quickly as possible and prior to spraying with water. Use ice, if feasible, but not in the product directly, as it will tend to remove the TBC. If placed in the product, ice should be in a sealed metal container.
3. Keep vessel vented.
4. Dilute with ethylbenzene or toluene if tank is not venting and product temperature is below 231°F (110°C) to retard polymerization and reduce viscosity.
5. If possible remove product from tank before it solidifies, to save the tank. Use drums, diked area, or float on water.

INHIBITION

TBC (4-tert-butylcatechol) is customarily added to styrene to prevent polymer formation and oxidative degradation during shipment and subsequent storage.

Inhibitors prevent polymerization in two ways. (1) They can react with and deactivate the free radical in a growing chain. (2) They can act as an antioxidant and prevent polymerization by reacting with oxidation products in the monomer. It should be noted that sufficient oxygen must be present for inhibition. In the absence of oxygen polymerization will proceed as if no inhibitor were present.

The TBC level should be checked at regular intervals. (See Table 2B of this section) Additional inhibitor should be added to maintain a safe level.

The time required for TBC concentrations to fall to a dangerously low level varies greatly because of different storage and handling conditions. The depletion rates in actual storage may be appreciably faster or slower depending on the set of environmental conditions. Factors which affect depletion of

TBC are heat, water and air, with heat being the most important.

If the inhibitor has been depleted and polymerization has begun, inhibitor should be added immediately. If unstable monomer is not treated promptly, it may become unsalvageable.

Additional inhibitor should be added when inhibitor levels drops below 10 ppm to maintain adequate inhibition. Normal levels are 10-15 ppm, but some customers require up to 60 ppm because of unique storage conditions or process requirements. After addition, the storage tank should be recirculated until inhibitor is uniformly mixed and testing shows that target levels have been achieved. The tank should also be aerated to provide the proper amount of dissolved oxygen. Refer to Table 3A or 3B to determine proper amount of inhibitor to add.

The relatively small quantities of TBC required to raise the inhibitor level in stored monomer can most easily be added by using an 85% TBC/15% Methanol blend or a concentrated stock solution in the monomer or other solvent. Concentrated stock solution has an indefinite storage life when stored in the dark at normal ambient temperatures.

A TBC concentrate for use in increasing the inhibitor level in styrene monomer can be prepared by dissolving 704 grams of pure TBC in 1 gal of styrene monomer (186 gram/liter). At this concentration, 1 cc of the concentrate will raise the level of inhibitor 1 ppm in a drum of styrene having a net weight of 410 pounds. Table 3A lists the amount of concentrate required to increase the inhibitor level of bulk quantities by 10 ppm.

Styrene vapors in storage tanks are not inhibited and can polymerize on roofs of storage tanks and around vents. Vapor space inhibitors are available but are not viewed as being adequately effective.

SPECIAL NOTE - USE OF SOLID TBC

TBC is also available in a solid or crystal form. When packaged in a polystyrene bag of various sizes, the TBC can be added to the styrene by simply adding the prescribed amount (see Table 3C) to the tank (trailer, tank container, rail car, or vessel). The styrene monomer will dissolve the polystyrene bag

containing the crystal. TBC Crystal will dissolve with mixing in 20 to 60 minutes.

Caution: Personal Protective Equipment is required for handling solid TBC. In Addition, solid TBC inventory must be monitored in storage. The recommended shelf life of a polystyrene bag containing TBC is no more than 12 months (365 days), at which time the solid TBC may be recycled and re-packaged.

Table 1**Effect of Inhibitor and Oxygen on the Shelf Life of Styrene at Various Temperatures**

Temp.	12 ppm TBC		50 ppm TBC Saturated with Air
	Saturated with Air	Less than 3ppm O ₂	
15.6°C (60°F)	6 mo.	10 to 15 days	1 year
29.4°C (85°F)	3 mo.	4 to 5 days	6 months
43.3°C (110°F)	8 to 12 days	Less than 24 hours	Less than 30 days

Table 2A**Suggested Monitoring Schedule for Styrene Bulk Storage**

Monomer Temperature	Daily
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Table 2B**Suggested Testing Schedule for Styrene Bulk Storage**

Monomer Temperature	Frequency	Key Properties
26.7°C (80°F) or higher	Weekly	Polymer Inhibitor ASTM D2121 ASTM D4590
21.1 - 26.1°C (70 - 79°F)	Bi-weekly	Color Appearance ASTM D5386 or D1209 Visual
Below 21.1°C (70°F)	Monthly	Aldehydes Peroxides ASTM D2119 ASTM D2340

Color in styrene monomer can be reduced to acceptable limits by:

1. Distilling the colored monomer.
2. Blending with non-colored styrene. Caution should be used, however, since color does not always blend proportionately. Small trial blends should be made to determine the feasibility of this approach.
3. Passing the styrene over silica gel or alumina. This method has the disadvantage of removing the TBC inhibitor, which must be replaced. Acidic or highly-activated alumina may cause the styrene to polymerize. Verify the applicability of the material selected by using a small bench scale test.

PARTICULATE MATTER

Styrene should be free of particulate matter when it is polymerized. Although some particulate matter in styrene originates from outside contamination via the receiving-transfer system, it is also formed by the reaction of concentrated TBC solutions with iron. This may happen in lines which have contained styrene but have been blown dry.

Particulate matter in styrene may be avoided by:

1. Paying careful attention to cleanliness.
2. Properly coating the inside of tanks and transfer lines which may contain high concentrations of TBC or which may be blown dry after carrying TBC-inhibited styrene. Stainless steel vessels and lines are also recommended.
3. Filtering styrene to remove particulate matter before storage, shipment, or use.

DRUMS

Drums of styrene monomer should not be permitted to stand in the sun for more than a short period of time. As soon as possible after being received, drums should be moved to a cool, shaded area. In hot weather drums can be cooled with a water spray. It is also

advisable that inventories be kept to a minimum during summer months and that monomer is stored no longer than necessary. Adding additional TBC during hot weather is also recommended. Styrene should be stored in white drums that reflect sunlight as a means to control temperature.

TANKS

In designing bulk storage facilities, certain basic factors must be considered. Styrene monomer can be stored for relatively long periods of time if simple, but carefully prescribed conditions are met. In addition to the usual precautions taken with flammable liquids against fire and explosion hazards, precautions must be taken against conditions that will promote the formation of polymer and oxidation products. To accomplish this, the design and construction of a satisfactory bulk storage system for styrene requires careful consideration to eliminate excessive temperatures and to prevent contamination with polymer from infrequently used lines and other equipment. Figure 1 illustrates a typical tank design.

A self-supporting-type dome roof is recommended for vertical storage tanks. This type of construction simplifies the installation of linings and permits rapid drainage of uninhibited condensed vapors back into the liquid monomer, thus reducing the polymer and stalactite problem. Roof and sidewall openings above the normal liquid levels in the tank should be of large diameter and the number kept to a minimum.

Large diameter openings are easily lined and can also be used for dual-service purposes where feasible.

Insulation and refrigeration of storage tanks are recommended for environments where temperatures exceed 75°F for long periods of time.

Most consuming locations insulate storage tanks to dampen the effect of high day time temperatures but do not install refrigeration due to cost.

Lined carbon steel tanks are generally used for the bulk storage of styrene monomer.



**XTECHS
TESTINGS PVT LTD**

AN ISO 9001:2008 CERTIFIED COMPANY



MAGNETIC PARTICLE TESTING REPORT

COMPANY NAME	M/S. LG POLYMERS INDIA PVT. LTD.	REPORT NO.	17861	DATE	03.01.15
Test Equipment	SIMS	Testing Site	LG POLYMERS		
Magnetizing Current	AC / HWDC	Job Detail	WELD JOINTS 10% ON OUT SIDE		
Technique	YOKE	Inspection Authority	LG POLYMERS		
Magnetic Field	LONGITUDINAL	Material Specification			
Surface Preparation	SATISFACTORY	Test Blocks	PIE INDICATOR		
Back Ground	WELD JOINT	Test Specification	ASME SEC V ,SE - 709		
Testing method	Wet Method	Acceptance Standard	ASME SEC VIII, DIV 1		
		Demagnetization	-NA-		

Sl.No	Job Identification	Length (mm)	Thickness (mm)	Observations	Remarks
	M6 TANK				
1	North side to East side Bottom shell to Top shell	15		NO RELEVANT INDICATIONS	ACCEPTED

For XTECHS TESTINGS PVT LTD <i>G. Prithvi</i> LEVEL - II	TOTAL LENGTH 15.0 mts	CERTIFICATION OF JOB BY INSPECTION AUTHORITY
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*Original copy received.
Santosh
12/01/15*



XTECHS TESTINGS PVT LTD

AN ISO 9001:2008 CERTIFIED COMPANY



MAGNETIC PARTICLE TESTING REPORT

COMPANY NAME	M/S. LG POLYMERS INDIA PVT. LTD.	REPORT NO.	17862	DATE	05.01.15
Test Equipment	SIMS	Testing Site	LG POLYMERS		
Magnetizing Current	AC / HWDC	Job Detail	WELD JOINTS 10% ON OUT SIDE		
Technique	YOKE	Inspection Authority	LG POLYMERS		
Magnetic Field	LONGITUDINAL	Material Specification			
Surface Preparation	SATISFACTORY	Test Blocks	PIE INDICATOR		
Back Ground	WELD JOINT	Test Specification	ASME SEC V, SE - 709		
Testing method	Wet Method	Acceptance Standard	ASME SEC VIII, DIV 1		
		Demagnetization	-NA-		

Sl.No	Job Identification	Length (mm)	Thickness (mm)	Observations	Remarks
	M6 TANK				
1	South side to West side Bottom shell to Top shell	7.5		NO RELEVANT INDICATIONS	ACCEPTED
2	West side to North side Bottom shell to Top shell	7.5			

For XTECHS TESTINGS PVT LTD
Ge. An. Reddy
 LEVEL - II

TOTAL LEANGH 15.0 mts

CERTIFICATION OF JOB BY INSPECTION
 AUTHORITY

Copy Received
Sampath
 12/01/15

D.No.5-29-52, Thokada, Autonagar, Visakhapatnam - 530 012, A.P. INDIA, Ph : +91-891-3255789, 98481 87916,

Fax : 91-891-2700368 Web Site : www.xtechs.in, email : info@xtechs.in, rajwant@xtechs.in

Format No : XTPL/F 01

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91



XTECHS TESTINGS PVT LTD

AN ISO 9001:2008 CERTIFIED COMPANY



MAGNETIC PARTICLE TESTING REPORT

COMPANY NAME	M/S. LG POLYMERS INDIA PVT. LTD.	REPORT NO.	17863	DATE	06.01.15
Test Equipment	SIMS	Testing Site	LG POLYMERS		
Magnetizing Current	AC / HWDC	Job Detail	WELD JOINTS 10% ON TOP SIDE		
Technique	YOKE	Inspection Authority	LG POLYMERS		
Magnetic Field	LONGITUDINAL	Material Specification			
Surface Preparation	SATISFACTORY	Test Blocks	PIE INDICATOR		
Back Ground	WELD JOINT	Test Specification	ASME SEC V, SE - 709		
Testing method	Wet Method	Acceptance Standard	ASME SEC VIII, DIV 1		
		Demagnetization	-NA-		

Sl.No	Job Identification	Length (mm)	Thickness (mm)	Observations	Remarks
	M6 TANK				
1	Top Roof Plate	15		NO RELEVANT INDICATIONS	ACCEPTED

For XTECHS TESTINGS PVT LTD LEVEL - II	<i>Copy received</i> <i>12/01/15</i>	TOTAL LENGTH 15.0 mts	CERTIFICATION OF JOB BY INSPECTION AUTHORITY
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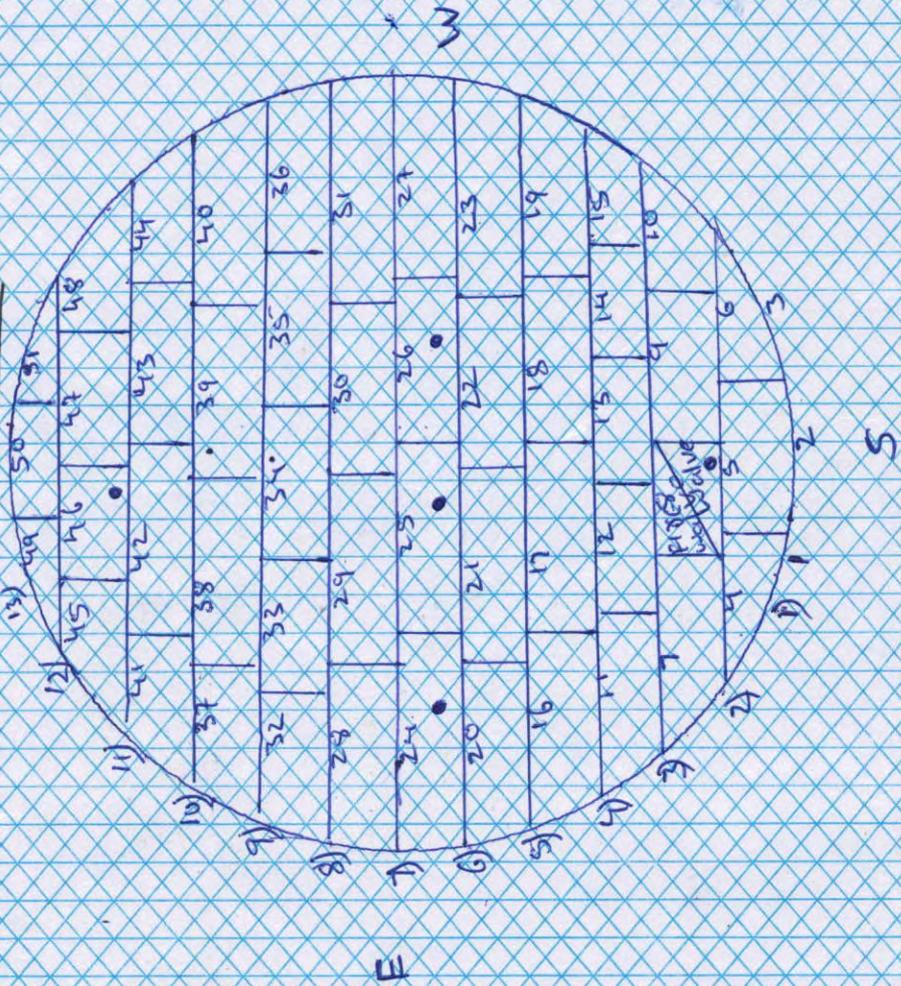
Copy received
12/01/15

Date: 18/12/14 TO 19/12/14.
Job Details: M6 TANK

Pipe Size :
Minimum Thickness : 6.5mm
Actual Thickness :

COMPANY NAME - LG POLYMERS

TOP ROPE PLATE



NK

ENGINEER NAME: Patran UNIT: OPERATOR NAME: G. Permi Reddy SIGNATURE WITH STAMP: G. Permi Reddy 18/12/14 INSTRUMENT: OLYMPUS 120027210

XTECHS
TESTINGS PVT LTD

AN ISO 9001:2008 CERTIFIED COMPANY
THOKADA, AUTONAGAR, VISAKHAPATNAM - 530 012.

Date: 18/12/2014
Job Details: M6 TANK

Pipe Size :
Minimum Thickness : 6.5mm
Actual Thickness :

COMPANY NAME - LGI POLYMERS

Sl. No.	TOP - ROPE PLATE EAST TO WEST	1st LINE	2nd LINE	3rd LINE	4th LINE
1)	7.4	7.2	7.4	7.5	8) 6.8
2)	7.5	7.7	7.4	7.6	9) 7.2
3)	7.4	7.2	7.5	7.2	10) 7.0
4)	7.2	7.0	6.9	7.4	11) 6.8
5)	7.2	6.8	7.0	7.4	12) 7.2
6)	7.0	6.6	7.4	7.2	13) 7.2
7)	7.5	7.2	7.4	7.5	14) 6.9
	7.0	6.9	7.4	7.2	15) 6.8
	7.2	7.6	7.5	7.0	16) 7.2
	7.0	6.8	7.2	7.4	17) 7.2
					18) 6.9
					19) 6.8
					20) 6.9
					21) 6.9
					22) 6.9
					23) 6.9
					24) 6.9
					25) 6.9
					26) 6.9
					27) 6.9
					28) 6.9
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					30) 6.9
					31) 6.9
					32) 6.9
					33) 6.9
					34) 6.9
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					36) 6.9
					37) 6.9
					38) 6.9
					39) 6.9
					40) 6.9
					41) 6.9
					42) 6.9
					43) 6.9
					44) 6.9
					45) 6.9
					46) 6.9
					47) 6.9
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					195) 6.9
					196) 6.9
					197) 6.9
					198) 6.9
					199) 6.9
					200) 6.9

TOTAL SPOTS: 109

TRUE COPY
94

ENGINEER NAME: POASEN
OPERATOR NAME: G. Ganani Reddy
SIGNATURE WITH STAMP: G. Ganani Reddy
INSTRUMENT: OLYMPUS
120027210

XTP/PF 17

ATECHS
TESTINGS PVT LTD

AN ISO 9001:2008 CERTIFIED COMPANY
THOKADA, AUTONAGAR, VISAKHAPATNAM - 530 012.

Pipe Size :
Minimum Thickness : 6.5mm
Actual Thickness :

Date : 19/12/14
Job Details : MG TANK

COMPANY NAME - LG POLY MERSINS

17)	7.4	7.9	7.4	27)	7.6	7.4	7.3	7.8	36)	7.1	7.6	7.9	7.4	
18)	7.4	7.9	6.9	7.6	7.1	7.0	6.8	7.4	37)	7.2	7.6	7.9	7.5	
19)	8.0	8.1	8.2	7.9	8.2	<u>8th LINE</u>								
20)	7.1	7.6	7.4	7.8	7.4	7.6	7.9	7.4	<u>10th LINE</u>					
21)	7.3	7.1	7.6	7.4	7.1	7.4	7.2	7.9	38)	7.1	6.4	6.8	6.9	
22)	7.7	8.1	7.9	7.9	8.0	7.4	7.3	7.1	7.6	39)	7.4	7.2	7.1	7.0
23)	7.1	7.1	7.2	7.9	7.1	7.9	7.7	6.9	7.2	40)	7.6	7.9	7.2	7.0
24)	8.1	7.8	7.9	8.0	<u>9th LINE</u>									
25)	7.1	7.2	7.4	7.1	7.4	7.3	7.1	7.6	7.9	41)	7.1	7.2	7.9	7.0
26)	8.0	7.8	7.9	7.4	8.0	8.0	8.0	7.4	7.1	<u>TOTAL SPOTS 102</u>				

ENGINEER NAME : PAWAN PAVAN
OPERATOR NAME : G. PAMI REDDY
SIGNATURE : G. PAMI REDDY
WITH STAMP : 19/12/14
INSTRUMENT : DTMPUS
120027210

TRUE COPY
95

XTP/LF 17

XTECHS

TESTINGS PVT LTD

AN ISO 9001:2008 CERTIFIED COMPANY
THOKADA, AUTONAGAR, VISAKHAPATNAM - 530 012.

Date: 19/12/2014.

Job Details: M6 TANK

Pipe Size :
Minimum Thickness : 6.5mm
Actual Thickness :

NK		COMPANY NAME - LGT POLY MERSICO	
11TH LINE		15TH LINE	
467	7.1	501	7.6
	7.4		7.2
	7.9		7.9
	8.0		7.4
	8.2		7.6
468	8.8	511	7.3
	9.2		7.9
	9.2		7.4
	9.2		7.0
469	7.1	521	7.1
	7.4		7.4
	7.6		6.9
	7.2		7.0
12TH LINE		TOTAL SPOTS: 44 SPOTS.	
466	8.0		
	7.9		
	7.4		
467	7.0		
	7.4		
	7.1		
468	7.9		
	7.6		
	7.2		
469	7.6		
	7.5		
	7.4		
	7.9		

ENGINEER NAME: PAVAN
 OPERATOR NAME: G. P. AMI REDDY
 SIGNATURE WITH STAMP: G. P. AMI REDDY
 INSTRUMENT: OLYMPOS
 UNIT: 19/12/14.
 120029210

Date: 17/12/2014

Job Details: Bottom Shell-1

XTECHS

TESTINGS PVT LID

AN ISO 9001:2008 CERTIFIED COMPANY

THOKADA, AUTONAGAR, VISAKHAPATNAM - 530 012.

Pipe Size :

Minimum Thickness : 15mm

Actual Thickness :

NK		BOTTOM SHELL-1		M6 TANK		COMPANY NAME - LGI POLYMERS	
<u>PLATE-1 (NORTH SIDE)</u>		<u>PLATE-4 (SOUTH SIDE)</u>		<u>PLATE-7</u>		<u>PLATE-10</u>	
1)	16.9 17.0 16.6	13)	16.4 16.8	24)	16.6 16.8 16.4	32)	16.4 16.2 16.4 16.8
2)	17.2 16.8 16.6	14)	16.2 16.8 16.4	25)	16.4 17.0 16.8	33)	16.8 1.66 16.4
3)	16.9 17.0 16.8	15)	16.6 16.4 16.8	26)	16.6 16.9 17.0	34)	16.2 15.9 16.4 16.8
4)	16.8 16.9 16.8	16)	16.8 17.0 16.8	27)	16.9 16.6 16.4	35)	16.6 16.4 16.8 16.2
<u>PLATE-2 (WEST SIDE)</u>		<u>PLATE-5</u>		<u>PLATE-8</u>		<u>PLATE-11</u>	
5)	16.9 16.6 16.8	17)	16.2 16.8 16.6	17)	16.9 16.8	36)	15.9 16.1 15.8 15.8
6)	17.2 16.9 17.0	18)	16.8 16.6 16.9	28)	16.4 16.8 16.8	37)	16.1 16.4 16.4 16.4
7)	16.9 17.1 16.8	19)	16.9 16.5 16.9	29)	16.4 16.8 16.8	38)	16.8 16.4 16.0 15.9
8)	17.0 16.8 16.9	20)	17.1 16.8 16.2	30)	16.9 16.7 16.9	39)	15.8 16.1 15.5 16.0
<u>PLATE</u>		<u>PLATE-6</u>		PLATE		TOTAL SPOTS	
9)	16.9 16.6 16.8	21)	16.4 16.8 16.4			16.4	
10)	17.0 16.8 16.9	22)	16.6 16.6 16.4			16.0	
11)	17.2 16.9 16.7	23)	16.8 16.6 16.4			15.5	
12)	16.9 17.0 16.8					16.4	

ENGINEER NAME: P. Srinivas UNIT: OPERATOR NAME: G. Prasad WITH STAMP SIGNATURE: G. Prasad. 17/12/14. INSTRUMENT OLYMPUS 12002710

Date: 03-01-15

Job Details: M6 Tank

XTECHS

TESTINGS PVT LTD
AN ISO 9001:2008 CERTIFIED COMPANY
THOKADA, AUTONAGAR, VISAKHAPATNAM - 530 012.

Pipe Size :
Minimum Thickness :
Actual Thickness :

Sl. No.	Company Name	Thickness	Remarks
M6 TANK			
<u>PLATE-2 North Side</u>			
1	13.0	13.1	12.8
2	13.1	13.2	13.6
3	13.4	13.0	13.2
<u>East Side</u>			
4	13.8	13.2	13.6
<u>South Side</u>			
5	13.0	12.8	11.8
6	13.2	12.9	13.1
<u>PLATE-3 North Side</u>			
7	10.6	11.2	10.8
8	12.3	11.5	10.8
9	12.3	10.4	10.9
<u>East Side</u>			
10	10.5	10.8	10.6
<u>South Side</u>			
11	10.9	10.6	10.4
12	11.0	10.5	10.7
13	11.3	10.8	11.1
<u>PLATE-4 North Side</u>			
14	10.4	11.4	10.3
<u>West Side</u>			
15	11.0	11.2	10.8
16	11.2	10.5	10.4
<u>PLATE-5 North Side</u>			
17	11.3	10.9	10.3
18	10.4	10.3	10.2
<u>East Side</u>			
19	10.6	11.1	10.2
<u>South Side</u>			
20	10.1	11.2	10.8
<u>West Side</u>			
21	10.3	11.4	10.6
22	10.2	11.2	10.5
<u>PLATE-6 North Side</u>			
23	8.3	8.4	8.8
<u>East Side</u>			
24	8.3	8.5	9.0
<u>South Side</u>			
25	8.2	8.6	8.4
26	9.2	9.0	8.8
<u>West Side</u>			
27	8.2	9.1	8.6
<u>Plate-6 North Side</u>			
28	8.0	8.3	8.5
29	8.6	9.0	8.4
<u>East Side</u>			
30	8.5	8.8	8.9
31	9.1	8.9	8.5
<u>South Side</u>			
32	9.4	9.1	8.8
33	8.1	8.6	8.4
<u>West Side</u>			
34	8.3	8.5	9.0
35	8.2	8.8	8.6
36	8.1	8.6	8.4
Total Spots			144

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98

XTP/LF/17

ENGINEER
NAME: Pawan

UNIT:

OPERATOR
NAME: G. Rami Reddy

SIGNATURE
WITH STAMP

03/01/15

INSTRUMENT
OLYMPUS
120027210

Date : 03-01-15

Job Details : MG Tank

XTECHS

TESTINGS PVT LTD

AN ISO 9001:2008 CERTIFIED COMPANY
THOKADA, AUTONAGAR, VISAKHAPATNAM - 530 012.

Pipe Size :

Minimum Thickness :

Actual Thickness :

171

MG TANK					COMPNY NAME - LG POLYMERS									
<u>PLATE - 7 North Side</u>					<u>PLATE - 8 North Side</u>					<u>PLATE - 9 North Side</u>				
37,	8.7	8.5	8.4	8.6	47,	8.2	8.5	8.7	8.1	56,	8.0	8.3	8.5	8.4
38	8.4	8.3	8.6	8.8	48	8.6	8.7	8.4	8.3	57	8.4	8.0	8.1	8.3
<u>East Side</u>					<u>East side</u>					<u>East side</u>				
39,	8.9	8.7	8.5	8.8	49	8.3	8.6	8.4	8.8	58	8.1	8.5	8.4	8.6
40,	8.6	8.4	8.8	8.7	50,	8.5	8.6	8.8	8.0	59	8.2	8.6	8.8	8.4
41,	8.5	8.9	8.6	8.4	<u>South Side</u>					<u>South Side</u>				
<u>South Side</u>					<u>South Side</u>					<u>South Side</u>				
42,	8.5	8.7	8.3	8.6	51,	8.2	8.1	8.4	8.6	60,	8.0	8.5	8.2	8.8
43,	8.4	8.6	8.8	8.9	52,	8.5	8.4	8.8	8.2	61,	8.1	8.3	8.5	8.6
44,	8.5	8.6	8.9	8.8	53,	8.4	8.8	8.6	8.3	62,	8.4	8.2	8.1	8.5
<u>West Side</u>					<u>West side</u>					<u>West side</u>				
<u>West Side</u>					<u>West side</u>					<u>West side</u>				
45,	8.8	8.6	8.5	8.9	54,	8.5	8.0	8.4	8.2	63,	8.6	8.5	8.4	8.1
46	8.7	8.6	8.8	8.4	55,	8.1	8.3	8.6	8.4	<u>Total spots 108</u>				

TRUE COPY

99

ENGINEER NAME : pawan

UNIT :

OPERATOR NAME : G. Ramu Reddy

SIGNATURE WITH STAMP : G. R. Reddy 03/01/15

INSTRUMENT OLYMPUS 120027210

XTPLF 17

Indian Standard

CODE OF PRACTICE FOR DESIGN,
FABRICATION AND ERECTION OF VERTICAL
MILD STEEL CYLINDRICAL WELDED
OIL STORAGE TANKS

(First Revision)

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BUREAU OF INDIAN STANDARDS
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NEW DELHI-110002

6.4 Designs of Roof

6.4.1 Definitions — The following definitions shall apply to designs of roofs.

6.4.1.1 Supported cone roof — A roof formed to approximately the surface of a right cone, with its principal support provided by either rafters on girders and columns or rafters on trusses with or without columns.

6.4.1.2 Self-supporting cone roof — A roof formed to approximately the surface of a right cone, supported only at its periphery.

6.4.1.3 Self-supporting dome roof — A roof formed to approximately a spherical surface, supported only at its periphery.

6.4.1.4 Self-supporting umbrella roof — A modified dome roof so formed that any horizontal section is a regular polygon with as many sides as there are roof plates, supported only at its periphery.

6.4.2 General

6.4.2.1 All roofs and supporting structures shall be designed to support dead load, plus a uniform live load of not less than $1\ 225\ \text{N/m}^2$ ($125\ \text{kgf/m}^2$) of projected area.

6.4.2.2 Roof plates shall have a minimum nominal thickness of 5 mm. A greater thickness may be required for self-supporting roofs (see 6.4.5 and 6.4.6).

6.4.2.3 Roof plates of supported cone roofs shall not be attached to the supporting members.

6.4.2.4 All internal and external structural members of the roof shall have a minimum nominal thickness, in any component, of 4.5 mm.

6.4.2.5 Roof plates shall be attached to the top angle of the tank with a continuous fillet weld on the top side only.

If the continuous fillet weld between the roof plates and the top angle does not exceed 5 mm and the slope of the roof at the top angle attachment does not exceed 1 in 6, the joint may be considered to be frangible and, in case of excessive internal pressure, will fail before failure occurs in the tank shell joints or the shell-to-bottom joint. Failure of the roof-to-shell joint may be accompanied by buckling of the top angle.

Where the weld size exceeds 5 mm or where the slope of the roof at the top-angle attachment is greater than 1 in 6, emergency venting devices in accordance with Appendix C shall be provided by the purchaser. The manufacturer shall provide a suitable tank connection for the device.

6.4.2.6 For all types of roofs, the plates may be stiffened by sections welded to the plates but not to the supporting rafters and/or girders.

6.4.3 Permissible Stresses — All parts of the structure shall be so proportion-

Annexure - D

Preliminary and Interim Expert Opinion of Dr. Rahul Nabar (8th Nov. 2020)

**PRELIMINARY AND INTERIM
EXPERT OPINION OF DR. RAHUL NABAR**

**STYRENE VAPOUR RELEASE INCIDENT
AT
LG POLYMERS INDIA PVT. LTD.
(VISAKHAPATNAM, INDIA)**

8th November 2020

I. SCOPE OF WORK AND QUALIFICATIONS

At the request of counsel for LG Polymers India Private Limited (“LGPI”), I was asked for professional opinions on certain issues arising from the vapour release at the LGPI facility in Visakhapatnam on 7 May, 2020. My opinion has been necessitated to assist LGPI in responding to litigation matters and to inquiry committees constituted to determine the root cause of the incident. Specifically, I have been asked to opine on, among other things, the storage and handling of styrene monomers, processes associated with styrene polymerisation (including storage) as well as events at and around the LGPI tank farm during the COVID-19 lockdown from 23 March 2020 through 7 May 2020. My opinions are based on a combination of my education, professional interest, training, and experience combined with an analysis of documentary literature and other proprietary facts made available to me.

I graduated with a Bachelor’s Degree in Chemical Engineering from the University of Mumbai (2003) and subsequently worked on doctoral research at the University of Wisconsin – Madison in the Department of Chemical & Biological Engineering. I received my Ph.D. (2009) from the University of Wisconsin – Madison studying the applications of simulation techniques to selected problems in hydrocarbon (petroleum) processing. During my Ph.D. I worked on several projects related to Catalysis sponsored by the US-Department of Energy and private sector Oil and Gas companies with a focus on Gas to Liquid conversions and catalyst-poisoning. Subsequent to my Ph.D. I completed post-doctoral research at the University of Wisconsin (2009-2010) with a combination of experiments and simulations related to petrochemical processes. I also led a project for high-performance scientific computing (HPC) for Chemical Engineering applications at the University of Wisconsin.

I presently work as an independent consultant in the chemical industry. My primary domains of interest include process-engineering, regulatory affairs, and process development with a focus on fine / specialty chemicals. In this context, I have been working on projects that utilize styrene for chemical processes at industrial and lab scale and hence developed a professional interest in the body of knowledge regarding the safe storage and handling of styrene and also the phenomenon of auto-polymerisation and strategies to prevent it. My projects tend to be at the interface of industrial practice and academic research. I am presently also teaching as an Adjunct Associate Professor at the Indian Institute of Technology, Bombay where my principal academic and scientific focus is teaching students about industrial practices especially in the context of fine chemicals. I lecture on chemicals-related topics at several other educational institutions in the city of Mumbai. My current professional interests include projects that bridge the gap between academia and industry and ways to enhance process safety in the Indian chemicals industry.

A copy of my CV is provided as an Appendix.

A. Scope of Work

The scope of my work is to gather and analyze facts relating to the vapour release incident at LGPI on 7 May 2020 and to come to opinions based on those facts, on existing scientific and engineering literature, and on my education and experience. This includes specifically an analysis of the chemistry, engineering and design and operational systems involved. This excludes analysis of toxicology, ecotoxicology and health effects of the release (if any) and also regulatory aspects and governmental compliances. This scope defines the overall scope of my assignment and not specifically the scope of this report which conveys only my preliminary opinions based on the materials made available at this time. Specifically, the purpose of this interim report is to address some of the findings of the NGT committee reports dated 7th May and 28th May 2020.

B. Limitations of the Interim Report

The nature of this report is interim and preliminary. It is premature to arrive at final professional conclusions at this stage in the investigation. The COVID-19 lockdown has prevented travel to the LGPI site and prevented on-site inspections. Governmental authorities additionally have closed and prevented access to the LGPI facility. As more information becomes available portions of this report may be revised and/or supplemented.

II. DESCRIPTION OF THE INCIDENT

The incident in question is a vapour release of styrene from the M6 storage tank on the LGPI manufacturing site in the early morning of 7 May 2020. The following is a brief summary of the incident evolution.

Tank M6 is a cylindrical, atmospheric, fixed-roof, insulated storage tank used for the storage of styrene monomer and located in a dyked area within a tank farm on the LGPI site. It is made of carbon steel, is 18 metres in diameter and 12 metres tall, and has a capacity of 2800 metric tons. At around 02:58 AM on 7 May, gas-detector alarms related to the M6 tank were triggered in a control room on the LGPI site (GPPS control room; the tank farm did not have a separate control room).¹

Immediately, LGPI operators tried to approach the tank but could not get close on account of a thick, white vapour cloud that stretched close to the ground level. However, visual confirmation was obtained that vapour was emanating from the M6 tank from at least two visible spots. We now know that one of the vapour plumes was originating from a 8-inch, open dip-hatch on the M6 roof, whereas another originated laterally from an opening created by a weld joint separation on the shell-roof joint. With the prevailing wind the vapour plumes spread towards the boundary wall of the site across a vegetation patch internal to the site. The visible plumes remained thick for the first 20 to 30 minutes of the incident and then decreased (over the course of the incident the intensity has varied).

¹ For the purposes of this incident description, wherever available, time listed is consistent with IST. The CCTV Video is 16 minutes behind IST. The DCS time is approximately 4 minutes behind IST. Times should be considered approximate for the purpose of this incident description.

At some point the responders had to retreat to the main gate of the plant due to the spread of the vapour cloud.² Another styrene tank (M5) and a pentane tank is located close to M6. All these tanks have external water sprinkler systems which were then manually activated by the LGPI employees.

At 5:01 AM the M6 refrigeration system was turned on. At 05:11 AM, the inhibitor NDM³ was injected into the tank via a day-tank and associated pump. This injection was through a nozzle close to the bottom and seems to have worked in reducing the vapour release intensity. Subsequently till 06:00 AM, more additions of NDM and Eunox were done to the M6 tank. Around 06:41 AM, some styrene was transferred to other tanks but the amounts were limited due to lack of available suitable tanks.

Around 08:15 AM, another inhibitor, TDM, was dosed into the tank but this time the foam pourer nozzle (N2; 500 mm) on the tank roof was employed to inject chemicals into the top portion of the tank (pumping via the Fire Crash Tender pumps). In the interim period (at 8:30 AM), Tank 1221A was made ready and additional styrene was transferred out of M6 into this tank without the use of pumps. By 10:30 AM, the styrene temperatures in M6 had risen to 42°C (as measured by the control system (“DCS”) sensor at the bottom) and hence further pumping operations were stopped. Water was also pumped into the tank in order to cool the styrene.

The tank temperature (as measured by the bottom sensor in M6), which was close to 17°C the night prior to the incident, rose as the incident progressed. (See Figure 1, Figure 2).

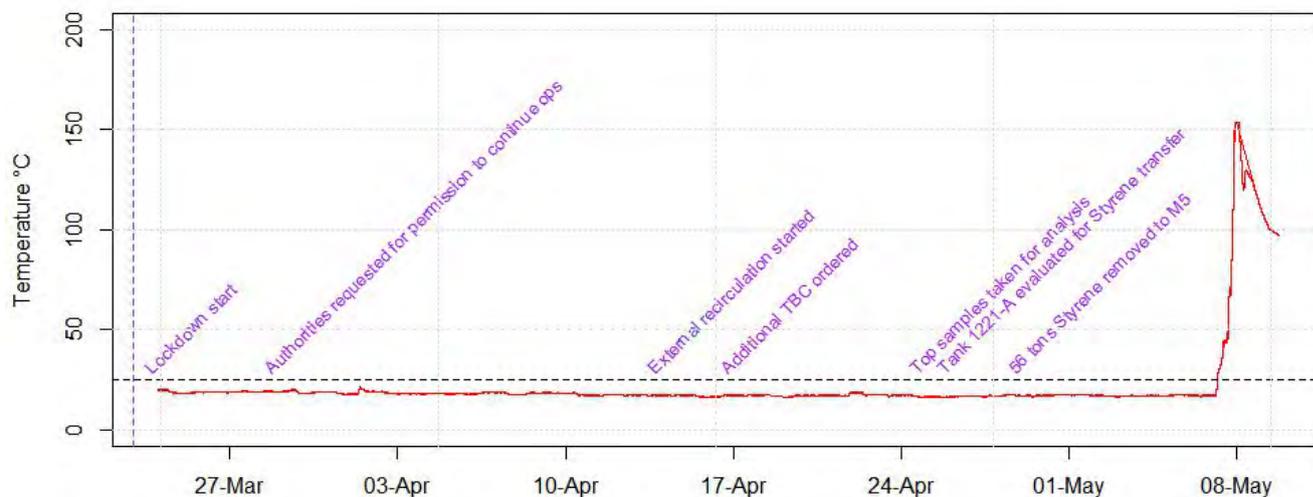


Figure 1: Recorded temperature of the Tank M6 (DCS) during the lockdown and the vapour release incident.

² Further details of the emergency response are beyond the scope of this report.

³ NDM and TDM have been referred to as inhibitors, but they should rightly be classified as chain transfer agents. They clearly seem to have worked at mitigating the vapour release.

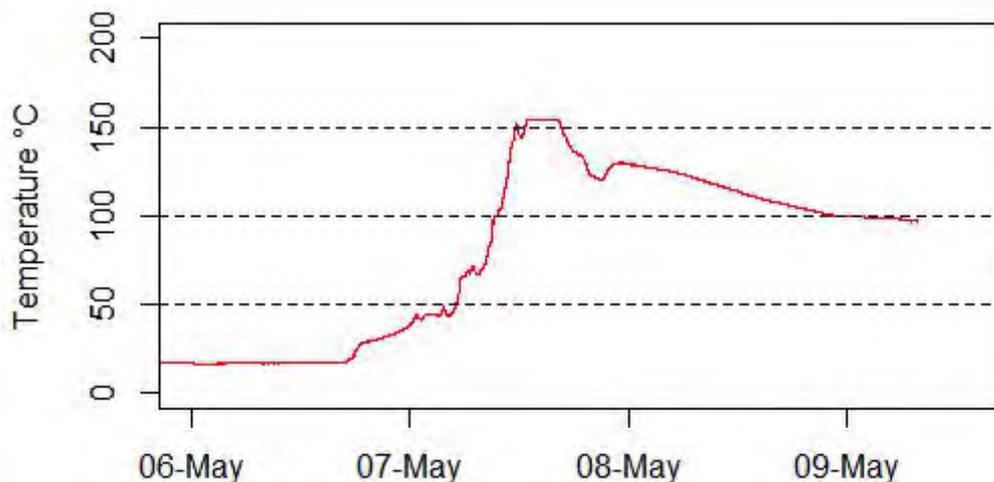


Figure 2: M6 temperature evolution (DCS) during the course of the vapour release incident.

Currently the exact state of the internals of tank M6 is not known. The site has been sealed off by regulatory / judicial authorities and access is restricted. It is thought that a majority of the styrene in M6 is fully polymerised into a solid state. The styrene that was pumped out of M6 during the incident was subsequently transported out of the site on directions from appropriate authorities.

Prelude to the actual incident of 7 May

The LGPI site had ceased production following the Indian Government's announced lockdown for COVID-19 on 24 March 2020. Styrene was stored in tanks M5 and M6 onsite and additional quantities were added during the course of the lockdown as additional styrene was delivered. As soon as the lockdown was imposed, on 23 March 2020, LGPI requested permission to keep some continuous production running; but LGPI's request was not granted by the local authorities. However, skeletal staff (15 employees per 8-hour shift) were granted passes to be onsite.

Tank monitoring revealed that TBC inhibitor content was around 15 ppm throughout the duration of the lockdown. M6 parameter monitoring was regular but at a reduced frequency than normal operations. Styrene temperatures were continuously measured and remained consistently below 20°C. Refrigeration of styrene (by circulating it through an external heat exchanger system) was practiced daily during daytime hours. A summary of polymer content measurements of M6 (bottom sample analysis) were as follows: 7 April-40 ppm; 28 April-320 ppm; 2 May-437 ppm; and 5 May-413 ppm. (See Figure 3). LGPI personnel reasonably interpreted the polymer content as a sign of polymer chunk dissolution and not auto-polymerisation. Actions taken accordingly included attempts to reduce M6 tank levels and preparation for plant restart to consume the M6 styrene. Recirculation of M6 styrene was also attempted⁴ from 13 April to 28 April using a 60 m³/hr pump for about 8 hours a day each alternate day.

⁴ This was via a temporary piping arrangement improvised by LGPI personnel on urgent basis.

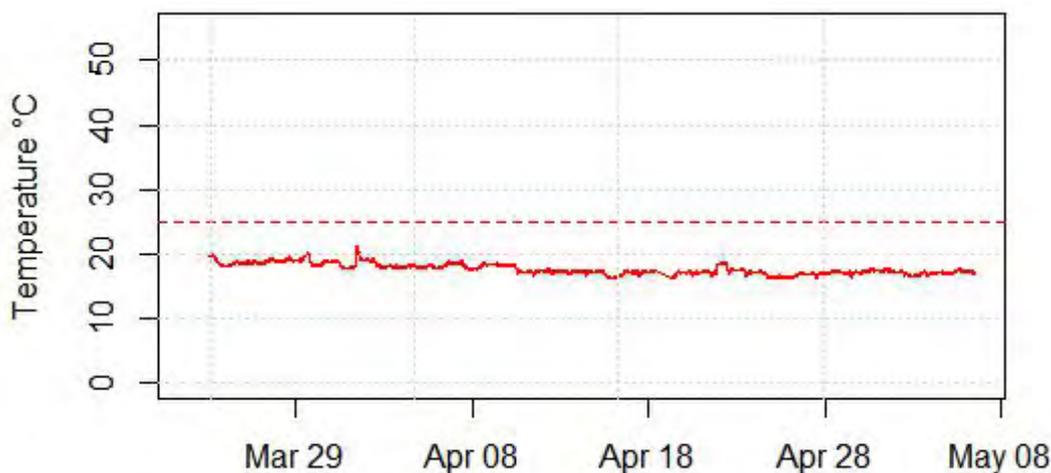


Figure 5: Temperature measurements (DCS) for Tank M6 during the COVID-19 lockdown period.

III. PRELIMINARY OPINIONS

Based on my review of the materials available to date, I have come to the following preliminary opinions and conclusions:

- A. Uninhibited Styrene monomer has an innate tendency to polymerise, which can increase polymer content and cause temperature to rise.

Styrene has a propensity to polymerise and left to itself will polymerise given enough time (Ref. 1, Ref. 10, Ref. 14). Polymerisation is not desirable from both a quality and a safety perspective. The polymerisation of styrene is an exothermic process (17.8 kcal/gm-mole) (Ref. 13, Ref. 14) and the heat released will have the effect of raising the temperature of styrene (unless it is carried away or removed due to some mechanism). Large, insulated tanks of styrene could be expected to function closer to adiabatic conditions—*i.e.*, they do not transfer efficiently a large quantity of heat to the ambient atmosphere outside the tank.

Another well-known observation is that the rate of chemical reactions, including polymerisation, increases with increasing temperature. Once the temperature of styrene rises, the rate of polymerisation increases and this leads to even more generation of heat. This release of heat causes a temperature rise, which in turn causes polymerisation to speed up, which then causes an even more rapid temperature rise⁵. Polymerisation also causes the styrene viscosity to increase, which then reduces heat transfer and hence will again cause more rapid temperature

⁵ This chain of events is sometimes referred to in literature as the Trommsdorf-Smith-Norrish gel effect. (Ref. 18, Ref. 41)

rise. (Ref. 21, Ref. 26, Ref. 42) All these factors can result in a “*positive feedback loop*” under certain situations which will aggravate the effect of small initial disturbances in the tank.

A positive feedback loop, if left unchecked, results in an ever-accelerating self-polymerisation that ultimately could result in a large mass of styrene boiling (at 145°C) followed by the generation of large amounts of hot styrene vapours (Ref. 3). This process can cause catastrophic tank failures followed by a fire and explosion. These risks, and examples of what happens when those risks are realized, have been known and have recurred throughout the over eight decades of history of styrene handling (Ref. 2, Ref. 6, Ref. 10, Ref. 26, Ref. 40).

A number of mechanisms are used to prevent this self-polymerisation of styrene, including the addition of inhibitors such as Para Tertiary Butyl Catechol (TBC). (Ref. 1, Ref. 12, Ref. 30, Ref. 31) Under normal circumstances, 10 to 20 ppm of TBC are added to styrene after its production and serve to keep polymerisation under control during the typical shipping and handling, until the styrene is consumed in production⁶ (Ref. 9, Ref. 11, Ref. 14, Ref. 19). Typically, quality concerns will already take place at polymer ppm levels lower than the point where safety concerns arise⁷; hence, producers, handlers, and users of styrene have a natural incentive to optimize the use of inhibitors and keep polymerisation to a minimum. Polymerisation can never be reduced to zero levels; it is just reduced to the point where there are no concerns of safety or quality.

LGPI, like any other styrene consumer, has an incentive to keep polymer content and temperature in control from both a quality and safety standpoint. In this context, the goals of safety and quality are aligned naturally.

B. The polystyrene production industry customarily requires continuous operation.⁸

LGPI processes were based on the premise of regular consumption of on-site styrene and the mixing of on-site styrene with fresh, low-polymer content styrene in order to preserve product quality, to prevent auto-polymerisation, and to avoid the hazards and dangers associated with auto-polymerisation. The withholding of Government permissions to allow the plant to function during the lockdown (in spite of the plant being a continuous plant and having unique hazards relating to stoppage) (Ref. 39) precipitated the unique hazard of storing styrene for long durations at a facility not used to such stagnation (without the replenishment of fresh styrene monomer involved in normal operations).

C. LGPI, prior to the lockdown, never envisaged the need to store styrene monomer for 45 days as a possible scenario.

⁶ TBC requires oxygen to function effectively. Ref. 19 notes “*Polymerising cargoes such as styrene are often inhibited. Their carriage is somewhat unusual, in that the effectiveness of the inhibitor is increased in the presence of oxygen*”

⁷ e.g. Ref. 15 page 55 states “*Storage times in excess of 3 to 6 months should be avoided to minimize degradation of styrene quality.*”

⁸ Ref. 41 tells us “*Most PS [poly styrene] is manufactured using continuous bulk polymerization plants.....Because it is a continuous polymerization process, material-handling problems are minimized during manufacture.*”

There was never a need for storage of styrene monomer close to this duration over the decades of operating experience at the facility. Circumstances unique to the COVID-19 virus, attendant lockdown, and the declination of LGPI's request to be permitted continuous operation created a requirement to store styrene monomer for a long period of time.

D. LGPI was required without advance notice to manage long-term styrene storage in four large tanks.

The LGPI facility had two large styrene tanks onsite (M5 & M6), and utilized two additional large shore tanks (TK-102 & TK-123). During the 45-day lockdown, those tanks were full of thousands of metric tons of styrene monomer. (See Figure 6). Styrene is a chemical that has a propensity to polymerise. The LGPI operators were required to manage those many tons of styrene held in storage without consumption for 45 days with limited manpower. LGPI's warning to the government authorities of the hazard, dangers, and risk of explosion was ignored and rejected. The request to continue operations to prevent those dangers was denied. The LGPI operators made good-faith efforts to manage the thousands of tons of styrene monomer across four tanks and across 45 days.

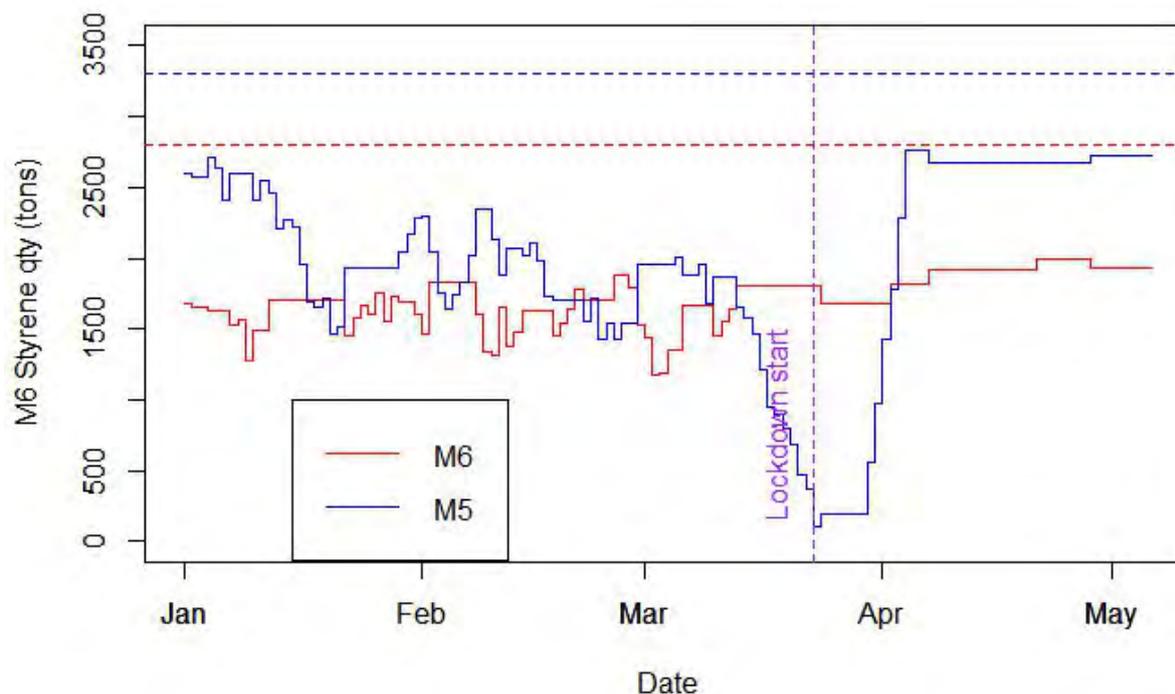


Figure 6: Styrene inventory of Tanks M5 and M6 during 2020.

E. The extended lockdown due to the COVID-19 pandemic was a necessary, initiating causal factor which precipitated other dormant factors to ultimately culminate in the tragic vapour release incident.

The design decisions and protocols in use at LGPI had worked successfully without incident for many years. Similar designs and protocols seem to be in use at other facilities globally. The one unique factor in this incident was the COVID-19-induced lockdown. The lockdown resulted in LGPI having to manage thousands of metric tons of liquid styrene, with

very few employees permitted onsite and with limited tangible resources available. As the styrene remained in the tanks, its natural propensity to auto-polymerise persisted. The auto-polymerisation about which LGPI had warned the authorities accelerated until its culmination in the vapour release on 7 May. The lockdown and its attendant restrictions set in motion a chain of events in the interior of the M6 tank (some portions and details of which are still unknown) which led to a catastrophe; under normal operating circumstances, this eventuality would be unlikely to occur on its own⁹.

F. The methods appropriate to control auto-polymerisation in production and in storage vary based on the specifics of the situation, including, but not limited to, tank size, geography, climate, and intended usage.

A range of methods are reported in literature for the control of styrene polymerisation during storage and handling. (Ref. 13, Ref. 14, Ref. 15, Ref. 16, Ref. 17) The appropriate methods to control auto-polymerisation in styrene vary based on the specifics of factors such as tank design, tank size, climatic conditions, and many others.

G. The customary methods of controlling auto-polymerisation can include some combination of the following strategies. Not all strategies are mandatory for every situation:

1. TBC added by the supplier (adjusted based on season/temperature).
2. The short residence time onsite.
3. Monitoring of temperature, TBC content, and polymer concentration.
4. Insulation.
5. Refrigeration.

The tank designer has leeway to include those features she/he deems appropriate to address the circumstance and purposes for each specific tank. Many tanks have fewer preventative or protective features than tanks M5 and M6. The shore tanks used by LGPI, for example, did not have either insulation or refrigeration. Rail cars, road tankers and ships used to transport styrene also typically do not have refrigeration (Ref. 2, Ref. 5, Ref. 15, Ref. 35).

H. Mitigation measures need only be used to the extent necessary to keep temperature at desired levels.

⁹ Tank features such as multiple temperature gauges and floating intakes are recommendations in some guidelines but not mandatory under any code known to us. The exact combination of systems used to protect a particular tank is left to the discretion of the design engineer. M6 and other Styrene tanks have operated safely for many years in the absence of such features.

Ambient temperatures fluctuate in daily and seasonal patterns, so also for a tank with cooling capability, which can increase or decrease the amount of active cooling necessary. The addition of warmer styrene from a non-refrigerated or uninsulated tank to a production tank can also raise tank temperatures and warrant active cooling. If tank insulation is sufficient during part of the day, a chiller or refrigeration system may be not required to be running 24-hours to keep styrene at recommended temperatures¹⁰ (Ref. 15 page 55).

The LGPI chiller or refrigeration system appropriately and effectively served two primary operational purposes: (a) to address the heat added by incoming styrene parcels from the shore tanks (*see* Figure 7), which were typically hotter than the styrene in M6 because the shore tanks were uninsulated and unrefrigerated, and that styrene was further transported approximately 15 kilometers to the plant via road trucks that were also uninsulated; and (b) to address daily solar heating and higher ambient temperatures which tend to increase temperature inside the tank (even though shell and roof of M6 were both insulated, some heat transfer would still occur).¹¹

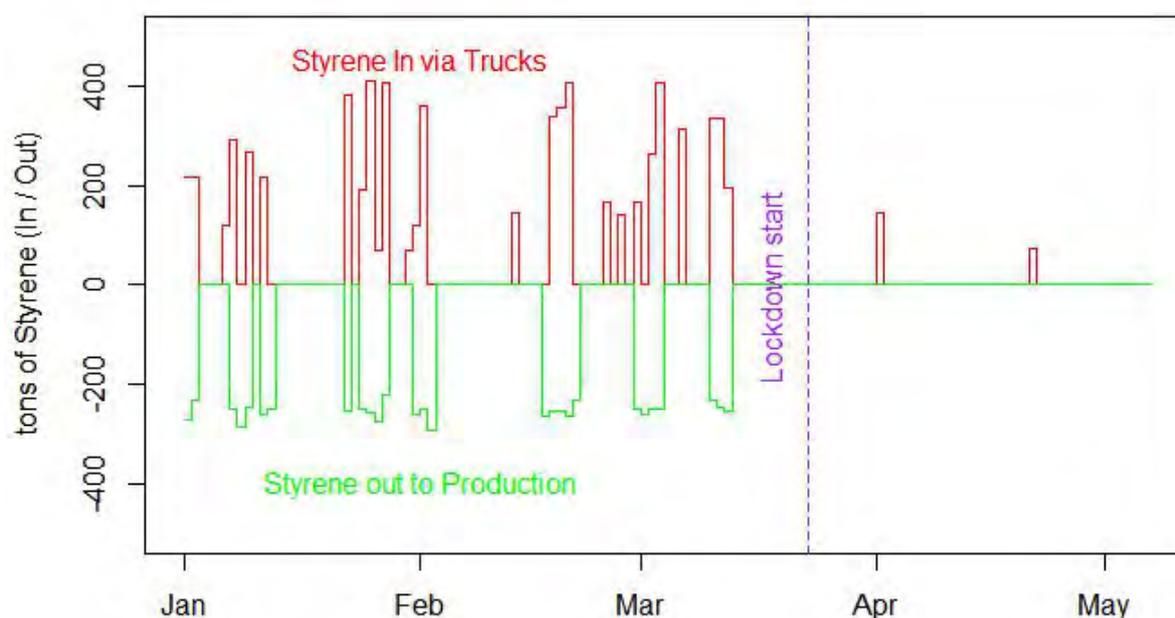


Figure 7: Styrene inflows to and outflows from Tank M6 tank in 2020.

- I. Each of the customary methods for polymer control and against auto-polymerisation was utilized in some form in tank M6.

The methods utilized at the LGPI site to prevent auto-polymerisation were a combination of purchasing monomer with sufficient TBC levels, circulation and mixing in the

¹⁰ Ref. 15 page 55 states “Styrene storage tanks do not normally require insulation or refrigeration unless extremely high temperatures are likely to be encountered.”

¹¹ The NGT found in its first *prima-facie* finding in its Interim Report, adopted in its Order dated 1 June 2020, that “Refrigeration system was not being operated fir [sic] 24 hours [per day].” NGT Order dated 1 June 2020 at 24. The finding is a factual statement that does not address whether there was any *need* to run the refrigeration system 24 hours a day. In my opinion, as set forth in section M there was not.

course of plant operation, sampling (of TBC levels and polymer concentration), temperature monitoring, insulation, and refrigeration:

1. LGPI specified to its styrene suppliers that incoming shipments should contain sufficient TBC to last during operational storage until consumption.
 2. As a function of the plant's intended continuous operation, older styrene was consumed and fresh styrene was added on a regular basis (see Figure 7), mixing and circulating the styrene in storage tanks.
 3. TBC and Polymer content of styrene were measured for tank M6 (and the other LGPI tanks), both before the lockdown and during the lockdown.
 4. M6 had a temperature monitoring sensor which read real-time temperatures and logged them in the DCS system. Hence, the tank temperature monitoring was essentially on a continuous or minute to minute basis.
 5. Tanks M5 and M6 employed external insulation (100 mm thick self-extinguishing, expanded polystyrene with bitumen bonding & vapour barrier + 24 SWG aluminium cladding (corrugated)).
 6. Tank M6 had an installed refrigeration system (38 TR cooling capacity; *Accel PWC-38 "Package Styrene Chiller Unit"*). Piping was in place which allowed emergency cross-circulation to utilize the refrigeration system of Tank M5 as well (38 TR cooling capacity). The refrigeration system was used regularly and daily during operation and during the lockdown.
- J.** Tanks M5 and M6 were maintained and operated for the purpose of feeding downstream polymerisation processes only on-site and not for long-term (e.g., 45-day) storage of styrene.

When the LGPI facility was operating, styrene was continuously consumed by downstream processes and fresh styrene was periodically transported from the shore tanks to replace it. As a result, the residence time of styrene in tanks M5 and M6 was typically rather short, such that there had never been a need to replenish TBC levels in tanks M5 or M6 prior to consumption. Historically, even when short shutdowns of plant processes were required, these shutdowns were staggered across the plant's production facilities to maintain some degree of continuous styrene consumption.

- K.** Third party risk analyses and safety audits of the site had been conducted previously, by multiple external agencies. None of these reports had anticipated a runaway polymerisation leading to a toxic release as a credible scenario or warned of substantive deficiencies in M6 design.

Over the LGPI facility's long operational history, there were various external agency audits. None of the third-party audits or regulatory inspections identified a deficiency or anticipated the risk of a toxic vapour release. For example, in a 2016 safety audit conducted by a third-party agency relating to the provisions of "IS: 14489: 1998 – Code of practice for Occupational Safety & Health audit and MSIHC Rules 1989," no substantive deficiencies relating to M6 were identified that might have prevented a vapour release as occurred on 7 May. To the contrary, the report says:

"Licensed storage premises of Styrene, Pentane, HSD & Liquid Paraffin dykes are well maintained. Safety protection systems are in place."

Similarly, a Quantitative Risk Assessment conducted in 2016-17 also did not include any mention of particular deficiencies or risks relevant to a toxic release, as opposed to the type of catastrophic rupture and explosion commonly associated with styrene incidents. An older Risk Assessment in 2001 specifically dealt with the styrene storage and again did not raise the risk of a toxic release of vapour. Rather, the focus was on catastrophic tank failure followed by a fire and explosion. Other audits reviewed had similar conclusions.

L. Government regulators regularly conducted on-site inspections without noting any substantial deficiencies in the M6 tank.

Annual inspections of the factory by the state factory-inspectors-department were conducted and recommendations were issued. Comments in these inspection reports do not seem to have identified any substantive deficiencies with the M6 tank, nor any recommendations that could have had a significant effect at averting this incident. Various critiques of M6 design and operations made subsequent to the incident are with the benefit of hindsight and it seems that neither LGPI employees nor the inspecting authorities had identified a toxic gas release as a credible scenario in all the years prior to this incident.

M. Continuous monitoring of tank M6 continued during the lockdown and revealed, among other indicators, the temperatures to be at or below recommended levels (25°C) throughout the 45-day lockdown period.

During the lockdown period, LGPI continued its sampling and analysis of the styrene tanks (TBC, polymer, moisture, temperature, etc.) as was its practice from when the plant was operating. None of this sampling and analysis suggested to LGPI employees an imminent vapour release.

N. Ongoing and continuous temperature measurements by the DCS indicated that it was not necessary to run the chilling plant 24 hours a day to maintain desired temperatures (<25°C) within M6.

The continuous DCS measurements of Tank M6's temperature sensor indicate that the temperature of styrene during the lockdown was regularly less than 20°C. Thus, as

continuously measured, the temperature of the styrene in M6 was much below the desired limit of 25°C. Hence, 24-hour operation of the refrigeration system was not necessary, and the LPGI operators did not believe that more refrigeration was required. Even in the pre-lockdown period, the tank did not use an around-the-clock chilling cycle¹².

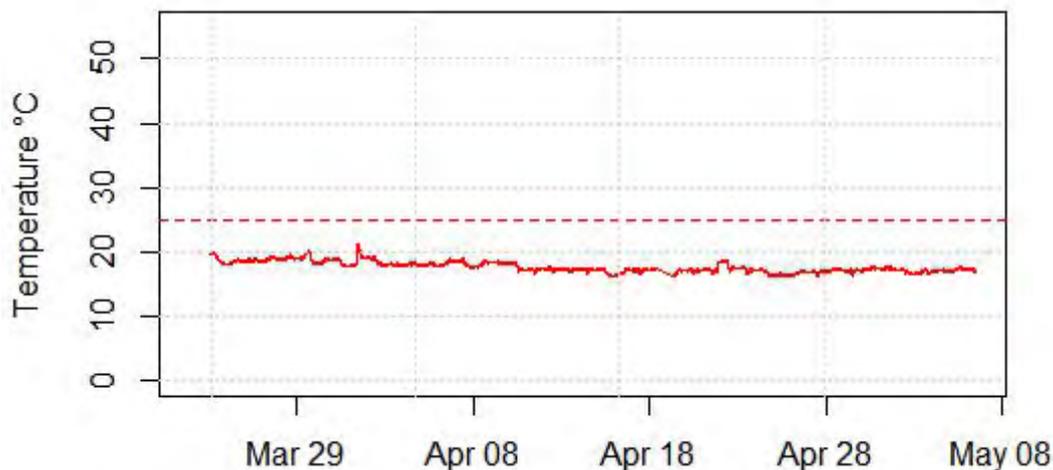


Figure 8: Temperature measurements (DCS) for Tank M6 during the COVID-19 lockdown period (repeated from above).

- Monitoring of the contents of tank M6 during lockdown revealed the TBC inhibitor content to be at and above recommended levels (10 ppm) throughout the 45-day lockdown period.

Styrene in M6 was monitored by LGPI for its TBC content throughout the 45-day lockdown. Analysis procedures used standard ASTM protocols (Ref. 7). The TBC inhibitor content was always around 15 ppm, which was within the limits of 10 to 20 ppm that was LGPI standard practice (see plot below); the measured inhibitor level never fell to or near the 10 ppm recommended lower limit. (See Figure 4). This was in line with industry recommended guidelines (Ref. 1, Ref. 4, Ref. 9, Ref. 11, Ref. 16) and analogous to TBC levels measured previously in the pre-lockdown period at the site and analogous to TBC levels in other tanks on site. (See Figure 9). A top-sample measured on 25 April also confirmed this same TBC level, *i.e.*, 15 ppm.

¹² None of the Guidelines mandate around the clock operation (or even the presence) of a refrigeration system. E.g. Ref. 15 writes “Styrene storage tanks do not normally require insulation or refrigeration unless extremely high temperatures are likely to be encountered.” Ref. 13 says “Most consuming locations insulate storage tanks to dampen the effect of high daytime temperatures but do not install refrigeration due to cost.”

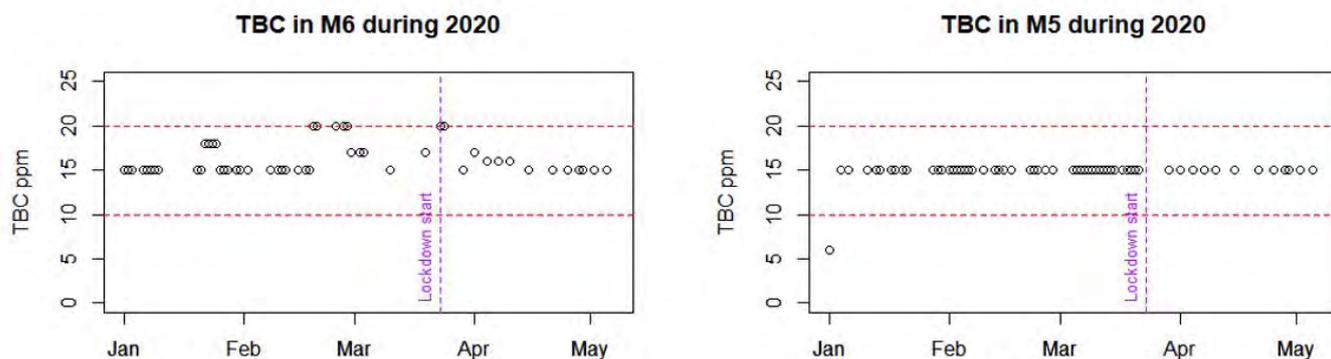


Figure 9: TBC measurements of Tanks M5 and M6 during 2020.

- P.** Based on LGPI’s regular monitoring of TBC levels in tanks M5 and M6, there was no perceived need for additional TBC to be added as the reported TBC levels were above the recommended levels throughout the lockdown and up to the time of the incident.

The observed TBC concentrations were stable and within the targeted and recommended levels throughout the lockdown period. TBC levels in Tank M6 were around 20 ppm when the lockdown started. This value decreased to 15 ppm and post 15 April through the incident date the TBC measurements remained stable at 15 ppm. This value was well above the limit of 10 ppm, and hence at no point did the TBC content measurements call for the addition of TBC. Historically, there was never a precedent for the LGPI operators having had to increase TBC levels in M6.

LGPI used its limited stock of TBC to protect the uninsulated and un-refrigerated shore tanks which, during the lockdown of indeterminate duration, were also required to store several thousand metric tons of styrene monomer and, thus, were more vulnerable to auto-polymerisation.

- Q.** The polymer levels observed in Tank M6 in late April did not signal to the operators an incipient or ongoing safety concern given the concurrently recorded TBC and temperature levels.

The data available to LGPI employees indicated that the polymer levels observed in tank M6 in late April were due to pre-existing polymer chunk dissolution and not due to auto-polymerisation. There was precedent at the site where higher polymer levels were detected due to polymer chunk dissolution¹³ especially when Styrene levels were high. In April 2020 such a situation indeed prevailed in Tank M6 (see Figure 10). On the other hand, in typical

¹³ Ref. 25 says: “This polymer formationalso amounts to a loss of monomer and when the bulk monomer contacts it, it dissolves in the monomer, resulting in a **reduction of quality** of the monomer.” Polymer dissolution was considered an issue primarily impacting quality and not safety.

polymerization scenarios, a temperature rise and a TBC level fall would be expected to concurrently happen (which was not what was observed in the prelude to this incident)

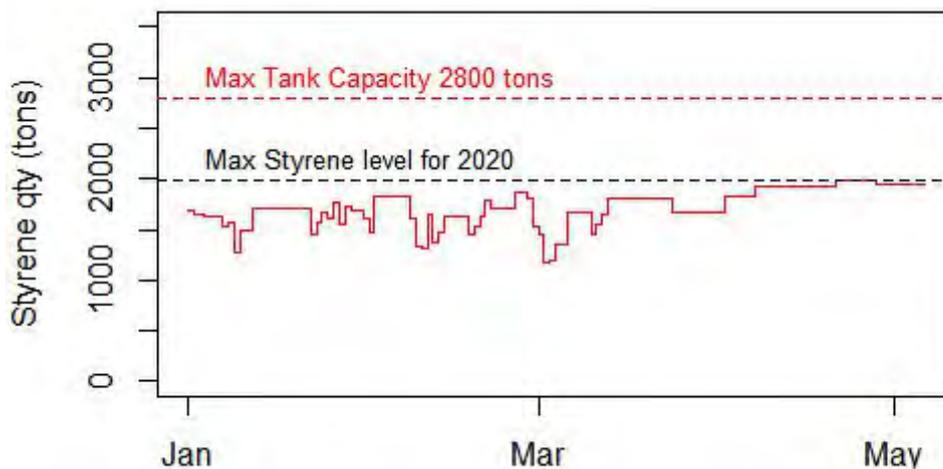


Figure 10: Styrene inventory variation of M6 tank in 2020.

- R.** The venting of the tank via the dip hatch and the weld joint separation (either during or prior to the incident) may have successfully prevented a catastrophic rupture of the tank.

There is generally an extensive history of past incidents related to styrene handling (Ref.2, Ref. 6, Ref.10, Ref. 24, Ref. 27, Ref. 40). A majority of those incidents resulted in damage due to fires or explosions. In the recent past, a shipboard styrene tank on the *Stolt Groenland* had one such catastrophic BLEVE (Boiling Liquid Expanding Vapour Explosion) with a distinctive fireball (Ref. 2). Another event relating to a road tanker transporting styrene in Taiwan also resulted in a BLEVE. Similar fires and explosions have caused destruction and fatalities in the context of styrene polymerisations (Ref. 26, Ref. 37).

Although the triggering cause for an auto-polymerisation can vary (and sometimes is never determined) the typical chain of events proceeds as follows: at some point the styrene heats up and the TBC gets either depleted or does not function well above 52°C.(Ref. 15) At this point the exothermic auto-polymerisation cycle continues to increase the temperature of the styrene (could be locally and gradually spreading through the mass of styrene). As the styrene heats up there is increasing vapour liberation. Some of the vapour gets vented but typically the vent sizes cannot cope and pressurization builds within the tank. If this process proceeds the styrene will eventually reach its atmospheric boiling point of approximately 145°C. (Ref. 1) At some point safe limits of structural design are exceeded, and a catastrophic tank failure occurs at some weak spot. This structural failure results in a loss of vapour containment and a styrene vapour cloud results from the sudden depressurization. Typically, some source of ignition is found and the vapour cloud ignites leading to fires and explosions.

In the case of the M6 tank, the existing open dip hatch (Nozzle N1; 8” diameter) on the tank roof allowed vapors to freely vent during the incident. In addition, there was a weld joint

separation at the shell-roof joint¹⁴ which also allowed additional venting capacity¹⁵. (Ref. 33) Both of these factors together, likely contributed to preventing a catastrophic failure of the M6 tank.

- S.** A fire / explosion / BLEVE did NOT occur. This fact is important, especially with large inventories of styrene and pentane at the plant and the proximity to habitation. It is likely that post-release actions of the LGPI team played a role in averting such even more tragic scenarios.

Many auto-polymerisation situations around the world have resulted in catastrophic tank rupture, explosions, and fires. (Ref. 2, Ref. 10, Ref. 37) No tank rupture, explosion, or fire occurred at LPGI. Had such a tank rupture and/or explosion occurred on 7 May or 8 May, the casualties and damage could have been much larger. It is likely, in my opinion, that some of the post-release actions of the LGPI team (taken at personal risk to their own lives and safety) played a role in averting such even more tragic scenarios.

- T.** The age of the M6 tank, by itself, does not seem to be an immediate / direct causal factor in the incident and other tank-related factors cannot be investigated due to restrictions on site access.

A significant majority of the storage tanks in industrial use for petrochemical storage are more than 30 years old. A US-GAO report (1995) (Ref. 38) revealed that 64% of API (American Petroleum Institute) tanks¹⁶ in use in the refining sector were older than 30 years (see chart below), with the majority of those being more than 40 years old. Large storage tanks are a significant capital expenditure and designed for long service lives. Tank safety is not a function of tank age alone.

¹⁴ It is not clear whether the weld joint separation happened during the incident due to overpressure or was pre-existing to the event.

¹⁵ Ref. 33 says: *“On a fixed-roof tank with a weak (frangible) roof-to-shell attachment as described in API Standard 650, the roof-to-shell connection will fail preferentially to any other joint and the excess pressure will be safely relieved if the normal venting capacity should prove inadequate.”*

¹⁶ *“API tanks”* refers to tanks built to follow the specifications of the API codes. M6 tank was intended to be in line with API650 specifications.

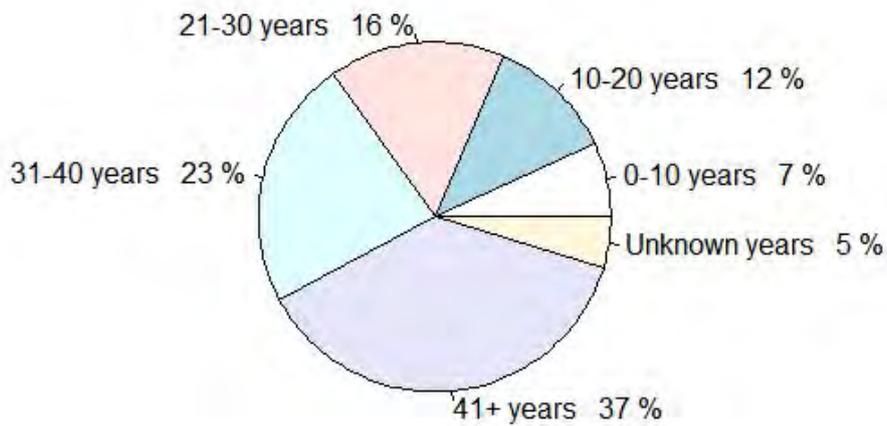


Figure 11: Survey of age distribution of API tanks in the Refining Sector by US-GAO (1995).
Sample size: 29,000 tanks.

Even in relatively new styrene tanks, runaway polymerisations and explosions have occurred. For example, the *Stolt Groenland* was only 10 years old when its styrene tank had a catastrophic explosion and subsequent fire in September 2019 at the port of Ulsan, Korea. (Ref. 2) As another example, in 2019, the *Stolt Focus* also had a near-miss incident with a styrene runaway in its 19-year-old tanks where a catastrophic explosion was fortunately averted (Ref. 2).

Many of the risk factors for a Styrene runaway may be design or protocol flaws where newness of a tank does not provide any natural protection. An older, but better designed, maintained and operated tank would be safer than a new tank with flaws. Any such conclusions based on M6 age alone are premature and unwarranted.

My above opinions (A to T) are preliminary and interim based upon: (1) the documents provided to me, (2) conversations with individuals at LGPI, (3) available scientific and engineering literature, and (4) my knowledge and experience in the area of chemical engineering and styrene handling.

This interim report has my preliminary opinions. My investigation is ongoing.

A handwritten signature in black ink that reads "R. P. Nabar". The letters are cursive and connected, with a distinct loop for the 'R' and a sharp peak for the 'P'.

Dr. Rahul Nabar

IV. RESPONSE TO SPECIFIC SECTIONS FROM THE NGT COMMITTEE REPORTS

A. Page 6 (Interim Report of the NGT Committee dtd. 17th May 2020)

(b) *Styrene is a reactive monomer and required to be stored preferable at temperatures of 15-18⁰C that is lower than ambient temperatures so that it doesn't polymerize. If the temperature approached 20⁰C the tank must be cooled and under no circumstances the temperature should exceed 25⁰C. Maintaining styrene temperature below its flash point of 31⁰C will prevent vapours from being in flammable range and maintaining the lower temperatures of 27⁰C extend the shelf life of styrene monomer. Usually Tertiary*

In my opinion 15°C to 18°C is an overly conservative requirement for the Storage of styrene. Such low temperatures are not justifiable based on most industry guidelines regarding styrene (e.g. Ref. 3, Ref. 14, Ref. 16).¹⁷ We note that Styrene is typically NOT transported as refrigerated cargo. Large quantities of Styrene are transported by road, rail and sea as ambient cargo where temperatures of 15°C to 18°C would be very difficult to maintain. Refrigeration must be provided when no other means exist to maintain tank temperatures within desired limits (Ref. 16 Lyondell Guidelines). In fact, the committee itself in a later paragraph of the report mentions a temperature of 27°C which we think is far more reasonable. Finally, even the industry guidelines for sampling frequency of stored Styrene include scenarios of 15 to

¹⁷ Ref. 3 the Indian BIS Styrene-Code of Safety says “Styrene polymerises rapidly if kept at temperature above 85 - 90°C even in presence of an inhibitor.” Ref. 14 (Chevron) says “Normally temperatures above 65°C (149°F) are needed to initiate runaway polymerizations.” Ref. 37 says: “The monomer has been involved in several plant-scale explosions, and must be stored at below 32 C, and for less than 3 months” Ref. 12 states “It is known that styrene will thermally polymerise at a temperature of 90°C, however, at this temperature the rate of thermal polymerisation is low....”

25°C and even > 25°C which clearly indicates that these are NOT temperature ranges which are excluded from allowable storage scenarios (Ref. 16 page 18; Ref. 15 page 13).

In this incident, the committee is considering a runaway polymerization scenario and not an ignition of styrene vapours in the ullage (vapor space) of the tank. Hence the flash point seems to be an unrelated parameter.

B. Page 8 (Interim Report of the NGT Committee dtd. 17th May 2020)

(d) An effective storage and handling of styrene monomer requires an inhibitor to be added to the tank. An effective inhibitor and a well-defined induction period that is period where no noticeable polymerization takes place shall be ensured. TBC is used with styrene monomer to increase the induction period, to be an effective inhibitor, TBC must have dissolved oxygen (above 6%) and a concentration of 15 ppm must be maintained in the tank. The TBC breaks down and consumes much faster at increased temperatures.

TBC is only an inhibitor. The dissolved oxygen would be in Styrene and NOT the TBC. In any case, the maximum equilibrium solubility of Oxygen in liquid Styrene is approximately 50 ppm (Ref. 15; page 14). Hence it is impossible to have a 6% concentration of dissolved oxygen in the Styrene as mentioned by the committee; this would indeed be much higher than even the equilibrium concentration of Oxygen. (Ref. 15; Figure 4; page 14) In our opinion, what the committee refers to is the vapor phase concentration of oxygen. Guidelines recommend a minimum of 3% (Ref. 15; page 14) and some guidelines mention that levels as low as 2% are adequate¹⁸ (Ref. 22, Ref. 34). The ullage (i.e. vapor space above the liquid level) of Tank M6 was in fact at atmospheric pressure and vented to ambient and hence Oxygen content could be expected to have been much higher than 6% at all times. The 6% limit is only applicable for tanks which are inerted intentionally with an oxygen deficient gas mixture (e.g. on board large marine transport (Ref. 34).

¹⁸ Ref. 34 says: “Although [oxygen] levels as low as 2% are adequate, levels of oxygen between 6% and 8% are preferred;”

C. Page 9 (Interim Report of the NGT Committee dtd. 17th May 2020)

(f) Monomers are thermally unstable. Standard European Behaviour Classification (SEBC) has classified styrene monomer as "floater evaporator". In the present incident, absence of TBC inhibitor, improper refrigeration and stagnant condition of styrene monomer (99.89% concentration) for about 45 days would have led to free radical polymerization of styrene molecules.

The SEBC classification applies primarily to marine spills of chemicals and classifies the oceanic spill dispersal behavior of Styrene. (Ref. 36) In our opinion this characterization has little impact on the storage of liquid styrene or its propensity for runaway polymerization as in this particular incident¹⁹.

The "*absence of TBC inhibitor*" that the committee mentions is not borne by facts. The Styrene stored in the M6 tank was indeed an TBC-inhibited parcel and TBC had been added to it by the manufacturer and subsequent measurements on the LGPI site validated the presence of TBC within known limits. Consequently, this scenario alluding to an "*absence of TBC*" is speculative.

D. Page 11 (Interim Report of the NGT Committee dtd. 17th May 2020)

¹⁹ Ref. 43 clarifies that "*The Standard European Behavior Classification (SEBC) codes provide a set of criteria for the theoretical evaluation of the short-term behavior of chemicals spilled in seawater according to their physicochemical characteristics.*"

20. *We are, prima-facie, of the view that styrene gas leakage from the affected tank was due to the following reasons :*

1. *Insufficient TBC concentration in styrene tank due to unavailability of TBC in the plant.*
2. *There is no monitoring system for dissolved oxygen in the vapour space which might have fall down below 6%.*
3. *The tank has no provision of monitoring temperatures at top layers of the storage.*
4. *Refrigeration system is not being operated for 24 hours.*

TBC concentration in the M6 tank was indeed regularly monitored during the shutdown period and was found to always be within specified limits (see Figure 4).

Monitoring systems for dissolved oxygen during Styrene storage are not mandated in any known guidelines or codes known to us (Ref. 13, Ref. 14, Ref. 15 & Ref. 16). In fact, it is meaningless to talk of dissolved oxygen (DO) in the vapor space in the first place. DO refers to the oxygen dissolved in the liquid styrene. The maximum value this can reach is 50 ppm and not 6% (Ref. 15, page 14). Vapor space monitoring of oxygen content is only recommended for installations which use an inert gas to pad the styrene. This is typically only done for large tanks on marine tankers due to unique circumstances (e.g. Ref. 34 IMO) and such inerting not in practice in the M6 tank. We don't find any credible scenario for the vapor space of this M6 tank to have been deficient in Oxygen below the 6% level.

The purpose of the chiller or refrigeration system was primarily to reduce the temperature of the warmer styrene delivered during continuous operation to the M6 tank from the uninsulated, unrefrigerated shore tanks and to compensate for daily solar heating. These goals were achieved without running the refrigeration system for all 24 hours daily (e.g. see Figure 5). Furthermore, none of the Guidelines for styrene storage require around-the-clock operation of a refrigeration system²⁰.

²⁰ Even the presence of a refrigeration system, in itself, is not a mandatory feature. Ref. 15 writes "Styrene storage tanks do not normally require insulation or refrigeration unless extremely high temperatures are likely to be encountered." Ref. 13 says "Most consuming locations insulate storage tanks to dampen the effect of high daytime temperatures but do not install refrigeration due to cost."

E. Page 14 of the NGT Committee Report dtd. 28th May 2020

which is called as a 'run-away reaction'. As the temperature rises, styrene starts vaporising. The pressure in the storage tank will progressively increase, and the safety valves released the styrene vapour into the atmosphere. The increase in temperature and pressure was not observed by the industry. Had the safety valve failed, the whole tank would have been exploded and still bigger catastrophe would have been happened.

The tank M6 was an atmospheric storage tank and did not have safety valves (it had instead open vents instead and a breather valve fitted with a flame arrestor)

F. Page 14 of the NGT Committee Report dtd. 28th May 2020

Styrene monomer with a boiling point of 145 °C, in liquid state remains monomer if it is maintained at low temperature preferably 15-18 °C. If the temperature approached 20 °C the tank must be cooled and under no circumstances the temperature should exceed 25 °C. If its

Addressed in Point A above.

G. Page 14 of the NGT Committee Report dtd. 28th May 2020

reaction again. This leads to exponential increase in reaction polymerization. The monomer styrene is toxic & severe without letting self-polymerization by adding inhibitor substance like Tertiary Butyl Catechol (TBC). This inhibitor works at low temperature below 25 °C. TBC is not effective as inhibitor of monomer Styrene at high temperature. Another chemical named N dodecyl

The generally accepted limit for TBC effectiveness is around 52°C and not 25 °C (Ref. 15, page 41 says "*At high temperatures (>52°C), TBC is not an active inhibitor*")

H. Page 15 of the NGT Committee Report dtd. 28th May 2020

There is no interlock system arrangement between the temperature and refrigeration system. There is no external water spray arrangement over the storage tank for exceeding ambient air temperature and also any unmanned hose arrangement.

The measured temperature of Tank M6 was always within limits and hence even if an interlock had been present, it is difficult to imagine how it might have changed the outcome of the incident. M6 was a tank with extensive external insulation; for such tanks an external water sprays would have had limited utility at cooling the tank (Ref. 15, page 41 says "*When the tank is insulated, insulation needs to be removed first, otherwise this [external water spray] has no effect at all.*") during the prelude to the incident. For comparison, the shore tanks at LGPI were uninsulated and external water sprays were used to cool them down during the lockdown period.

I. Page 16 of the NGT Committee Report dtd. 28th May 2020

temperature alert only came 8 minutes later. Mitigation of the impact could have been more effective had the chillers servicing Tank M6 been running. It was switched off at 5pm earlier that evening as per routine site practice as ambient night temperatures required little or no chilling. There was also no automated sprinkler arrangement for vapour loss as this had never

The design duty for the chillers was to cool the incoming parcels of styrene brought in to M6 by road tankers from the shore tanks. This Styrene was typically at a higher temperature since the shore tanks lacked chilling and insulation features. The chiller was expressly not designed to mitigate a full-blown runaway polymerization incident. In fact, sizing a chiller for such a duty would not be reasonable. Once a runaway polymerization incident has proceeded (to the point where visible vapor evolution from tank vents was seen) the heat of polymerization of Styrene is so large that the impact of the chillers would have been at best very marginal at best.²¹ Furthermore, in the immediate prelude to the event the temperature was being monitored and was within limits and hence there had been no perceived need to start the refrigeration system.

J. Page 16 of the NGT Committee Report dtd. 28th May 2020

The root cause thus appears to be the lack of experience of LG Polymers India and their Korean principal, LG Chem, in monitoring and maintaining full tanks of styrene that were idled for a long period of several weeks without operation. Further, M6 is an old tank in design terms and this possibly contributed to the problem. The breather vent through which the boiling styrene escaped was 8 inches in diameter, enabling very significant outflow at the high temperature and pressure generated by the runaway reaction. Operators and any industrial persons are not aware of control measures in such situation is the main cause.

The design intent of the vent is indeed to release Styrene vapours sufficiently rapidly so that the M6 tank itself would not be pressurized to a point beyond its structural limits. Had this “*significant outflow*” not occurred, then there was a very serious risk of the M6 tank itself facing catastrophic structural failure. The results of this could have been far more catastrophic e.g. Fire, explosion etc. which have been the more commonly reported outcomes of a Styrene runaway polymerization incident in the past during other incidents (e.g. Ref. 2, MAIB-UK). In that sense we think it is improper to fault the role of the vent or its size in this incident.

As clarified in an earlier section of this report (e.g. see Figure 11), the age of the M6 tank was, in itself, not unusual for tanks in refining & petrochemicals service in general (Ref. 38 US-GAO).

²¹ The heat of polymerization of styrene is 17.8 kcal / gmol (exothermic), the 38 TR refrigeration system would only be able to compensate for the increased heat of approximately the 670 kg of styrene polymerizing per hour. This is less than 0.1% of M6’s inventory at that time. Therefore, at the point where runaway polymerization had established itself, the refrigeration system, on its own, would not be capable of preventing the incident.

K. Page 20 of the NGT Committee Report dtd. 28th May 2020

16) Carbon steel and stainless steel are suitable for handling styrene and Blanketing of tanks for fire protection should be considered.

Blanketing of land-based Styrene storage tanks by inert gases (e.g. Nitrogen) is explicitly not a recommended protocol based on industry guidelines (Ref. 16 page 19, “*Nitrogen blanketing is only recommended for short-term storage.*”). The TBC inhibitor requires oxygen to function correctly and blanketing with an inert gas would interfere with the action of TBC²². (Ref. 19)

²² Ref. 15 page 12 warns that: “*Styrene should never be handled under an oxygen-free atmosphere*”

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APPENDIX

CV - DR. RAHUL NABAR

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Ph.D. Chemical Engineering University of Wisconsin-Madison, USA Focus: Petrochemical Processes	2009
B.E. (B.S.) Chemical Engineering University of Mumbai, India.	2003

Languages spoken

English, German, Hindi, Marathi

Professional Experience

Chemical Engineering Consultant	2011-present
<ul style="list-style-type: none"> Advising chemical companies in the domains of R&D, process development, feasibility studies and regulatory & product-certification requirements including EU-REACH, FAMI-QS, FCC etc. Evaluation of chemical plants from a process-safety and product-safety aspects (incl. HAZOPs and HACCP) Lab and pilot scale reaction optimization projects for 2-PEA (ex Styrene) and Methyl Pentenone (ex Acetaldehyde) Advising on data sharing disputes & chemical regulatory aspects under the REACH legal framework of the European Union 	
Adjunct Associate Professor IIT-Bombay (Dept. of Chemical Engineering)	2018-present
<ul style="list-style-type: none"> Teaching and research focus on Process Development in the Indian Fine & Specialty Chemicals Industry Improving safety in chemical industry through outreach, process modifications & digitalization 	
Post-doctoral Research Associate University of Wisconsin – Madison (Chemical Engineering)	2009 – 2010
<ul style="list-style-type: none"> Experimental & simulation studies for bio-fuels & Xylitol process development from biomass Studies into Fischer Tropsch Synthesis (catalysis) for Oil & Gas Industry 	
Project Leader: Scientific Supercomputing Cluster University of Wisconsin – Madison	2008 – 2011
<ul style="list-style-type: none"> Designed, installed and commissioned a ~20 Teraflops, 3000 core parallel computing cluster (Linux based) for petrochemical process and catalysis simulations 	
Project Researcher / Research Intern Exxon Mobil, Corporate Strategic Research (Chemical Catalysis group) – New Jersey, USA	2006-2007
<ul style="list-style-type: none"> Optimized catalytic formulations for petroleum refinery processes (Hydro-desulfurization) to produce Ultra-Low-Sulfur-Diesel (ULSD) [Joint US-DoE Exxon Project; based at UW 2006-2007 and at EMRE New Jersey Summer 2006] 	

Research Assistant

2003 – 2009

University of Wisconsin – Madison (Chemical Engineering)

- Catalysis improvement projects for Petrochemical processes incl. Fischer Tropsch Synthesis

Teaching Assistant

2005 - 2006

University of Wisconsin – Madison

- Instructed students in courses on “*Chemical Kinetics and Reactor Design*” and “*Process Design*” (*Capstone Graduation Project*)

Advisory / Teaching Assignments & Certifications

- Instructor for Continuing Education Program (CEP) for Industry Professionals IIT Bombay Dec 2019 “*Safety Data Sheets (SDS) in the context of EU exports & REACH Regulations*”
- Jury Member: *Young Chemical Engineers Award*, IChE, Institute for Chemical Technology-Mumbai 16th Feb 2020
- Lead Instructor qualification (*PCQI-LI*) from the *US-FDA* for **food industry safety compliance** under the US-FSMA legislation (May 2019)
- Sophia College, Mumbai (Dept. of Analytical Chemistry) 2019 & 2020
- Ruia College, Mumbai (Dept. of Chemistry) 2019
- Consultant- Caius Laboratory-St Xavier’s College, Mumbai 2016 – 2020
- Instructor-NMIMS, Mumbai (Biomedical Sciences Program) 2016

Membership of Professional Bodies

- Institution of Chemical Engineers, UK (AMIChemE)
- Professional Engineer (PE), Institution of Engineers (IEI) Reg. No. PE7003299
- Indian Institute of Chemical Engineers (life member)
- American Institute of Chemical Engineers
- American Chemical Society

Patents

- “*Continuous Production of Methyl Pentenone using Cation Exchange Resin in a Fixed Bed Reactor*” Indian Patent Application No.: 202021041062, Sept. 2020 Assignee: Indian Institute of Technology, Bombay (*patent application under examination*)

Workshops

1. “*Safer Complex Systems Workshop 2020: Regulatory Structures and Policymaking*” Oct 2020 Royal Academy of Engineering, UK
2. “*FAMI-QS South East Asia Local Working Group*” Member.
3. “*Next Generation Industrial Processes & Carbon Capture & Storage in Industry*” Session Chair 25-26 Feb 2020. *IITB-BP Symposium on Energy Transitions in Indian Industry*. IIT Bombay
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7. R. P. Nabar, A. Nilekar, M. Mavrikakis "Computational Chemistry-Based Identification of Ultra-Low Temperature Water-Gas-Shift Catalysts" US-DoE Technical Report OSTI ID: 945930. August 2008.
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9. R. P. Nabar, A. A. Gokhale, B. Critchfield, H Zou, M. Mavrikakis, C. H. Bartholomew and J. A. Dumesic "Atomic-Scale Design of Iron Fischer-Tropsch Catalysts" US-DoE Technical Report OSTI ID: 838346. March 2005.

Presentations & Invited Talks

1. R. P. Nabar "Process Development, Engineering and Scale up: From Lab to Production" Sept 2020. Invited Lecture. *AICTE - Faculty Development Program On Drug Engineering*. Bombay College of Pharmacy. Mumbai.
2. R. P. Nabar "The Chemical Industry in India: Challenges and Opportunities" Webinar. July 2020. Webinar Series: "*Aligning Industry Academia Interface*" Manipal University, Jaipur.
3. R. P. Nabar "Safety Practices in academic and industrial laboratories" Webinar. July 2020. Organized by IQAC, St Xaviers College, Mumbai
4. R. P. Nabar "Styrene & its safe handling & storage: Summary of industrial best practice" *Chemical Engineering Departmental Seminar*. 14 May 2020 Dept. of Chemical Engineering, IIT Bombay
5. R. P. Nabar "Overview of the Chemical Process Industry in India: The business and the Future" 2 March 2020. Emlyon, France *MBA-Course Invited Lecture*. St Xavier's College Mumbai.
6. R. P. Nabar, "Converting Academic Research to Practice: Tools, Tips, Opportunities and Pitfalls" 4th Feb 2020 Invited Talk at Workshop on "*Confluence 2020: Ignite and Innovate - Techniques in research*" St. Xaviers College, Mumbai
7. R. P. Nabar, Co-chair for the session "Green Chemistry for Speciality & Fine Chemicals Industry Sector" at the ICGW (Industrial Green Chemistry World) conference. IIT Bombay Mumbai. 17 Oct 2019.
8. R. P. Nabar, S. Mahajani "Industry academia collaboration in the Indian Fine Chemicals Industry" 17th Apr 2019 Invited talk at Chempspec India, Bombay Exhibition Center, Mumbai.
9. R. P. Nabar "Chemoinformatics" Feb-Mar 2019 Lecture Series. Sophia College Ruia College, Mumbai
10. R. P. Nabar "FAMI-QS implementation in India: a technology and engineering perspective" Dec 2018 FAMI-QS Workshop, organized by FAMI-QS, Belgium. Marriot, Mumbai.
11. R. P. Nabar "Safety in the Chemical Laboratory" Nov 2018 St. Xaviers College, Mumbai
12. R. P. Nabar "Applied Data Analytics for the Process Industries" Aug 2018 St. Xaviers College, Mumbai
13. R. P. Nabar; "There is plenty of room at the bottom! Problems and Opportunities in the Indian Fine Chemicals Industries" March 2018, Departmental Seminar, Dept. of Chemical Engineering, Indian Institute of Technology – Bombay (IITB)

14. R. P. Nabar; Invited lecture “Statistical Models in Chemical Engineering: An Applied Perspective” Feb 2017, Seminar on “Recent Techniques in Applied Statistics” Dept. of Statistics, University of Mumbai
15. R. P. Nabar, U. J. Dixit “Big Data Statistics: An applied perspective from Chemical Engineering” Dec 2016, Mukesh Patel School of Technology Management and Engineering, NMIMS, Mumbai
16. R. P. Nabar “Biosantalol: Indian Sandalwood Oil Synthesis by a Biotech Process” April 2016 Presentation before the Department of Biotechnology (DBT), BIRAC Review Committee. Center for Cellular and Molecular Platforms (C-CAMP)-Bangalore
17. R. P. Nabar, M. Mavrikakis “Application of High Performance Computing (HPC) to problems in catalytic petroleum processing: Fischer Tropsch Synthesis and the rational design of bimetallic-catalysts” Feb 2011, National Chemical Laboratories, Pune, India.
18. R. P. Nabar, M. Mavrikakis “Application of quantum mechanical calculations to selected problems in catalytic petroleum processing.” Jan 2011, Indian Institute of Technology, Mumbai India.
19. R. P. Nabar, M. Mavrikakis “Application of High Performance Computing (HPC) to Fischer Tropsch synthesis and the rational design of bimetallic-catalysts” Jan 2011, Institute of Chemical Technology, Mumbai India.
20. R. P. Nabar “High Performance Computing: A Chemical Engineering Perspective” Jan 2011, Computing Research Laboratories (CRL), Pune India
21. R. P. Nabar, M. Mavrikakis “Kinetics and Mechanisms of Fischer Tropsch Synthesis on Iron and Cobalt Catalysts” 2009 Spring Symposium, Catalysis Club of Chicago, May 2009, Chicago, IL.
22. R. P. Nabar, A. U. Nilekar, M. Mavrikakis, M. Ojeda, A. Ishikawa, E. Iglesia, “Mechanistic Insights on Fischer-Tropsch Synthesis” AIChE 2007 Annual Meeting, Salt Lake City, UT.
23. M. Ojeda, A. Ishikawa, R. P. Nabar, A. U. Nilekar, M. Mavrikakis, E. Iglesia “Fischer-Tropsch Synthesis Catalysis: Low-Temperature Fe Catalysts and the Mechanism for CO Dissociation on Fe and Co” 20th North American Meeting of the North American Catalysis Society(NAM), June 2007, Houston, TX
24. M. Ojeda, R. Nabar, A. Ishikawa, A. Nilekar, M. Mavrikakis, E. Iglesia, “On the Fischer-Tropsch Synthesis reaction mechanism on Fe and Co catalysts”, 8th Natural Gas Conversion Symposium, Natal, Brazil, May 27-31, 2007.
25. R. P. Nabar, J. M. McConnachie, T. A. Barchholtz, M. Mavrikakis “Sulfur tolerance of bimetallic alloys: A density functional theory study” 233rd ACS National Meeting, March 2007, Chicago, IL.
26. A. U. Nilekar, R. P. Nabar, Y. Xu, R. R. Adzic, M. Mavrikakis “Near-surface alloys for improved catalysis”, 232nd National Meeting of the American Chemical Society, Sept. 2006, San Francisco, CA.
27. C. H. Bartholomew, G. Huber, H. Zou, R. P. Nabar, P. Ferrin, M. Mavrikakis, J. Dumesic “Development of reliable, simple rate expressions from a microkinetic model of FTS on Cobalt”, 19th NAM meeting, May 2005, Philadelphia, PA.
28. A. A. Gokhale, R. P. Nabar, M. Mavrikakis, “A DFT study of Fischer-Tropsch Synthesis on Iron versus Cobalt surfaces”, AIChE 2004 Annual Meeting, Austin, TX