Texas A&M Engineering Experiment Station

TEXAS A&M UNIVERSITY

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I. INTRODUCTION

a. Instructions

1. I, Dr. Faisal Khan, Ph.D., was asked by Mr. Kokotsakis, on behalf of its client Victims of Railway Accident on February 28th 2023, to serve as an expert to analyze the fire accident causation and its potential impact.
2. In this capacity, I was asked to perform a fire accident type, source, causation and impact analysis based on the available video footage and other relevant data.
3. I have never previously worked for or served as an expert on behalf of Mr. Kokotsakis, or their respective counsel. I have never been engaged to provide expert witness testimony in connection with a legal action related to this accident.

b. Qualifications and Experience

4. I am a professor at Texas A&M University, where I am the Mike O'Connor Chair II of the Artie McFerrin Department of Chemical Engineering. I lecture on topics related to safety, risk, and reliability engineering.
5. I am also the Director of the Mary Kay O'Connor Process Safety Center (MKOPSC), which is the world's foremost university-based Process Safety Center. The Center serves industry, government, academia, and the public. It is a resource in education and research and provides service to all stakeholders. MKOPSC is guided by a Steering Committee of consortium member companies and a Technical Advisory Committee of industry experts. Industry guidance ensures that Center activities are relevant to the actual practice of process safety.
6. I served as Safety and Risk Advisor to the Government of Newfoundland, Canada, and other international agencies on the topic of safety and risk management.
7. I earned a Ph.D. in Environmental Engineering from Pondicherry University, India (1998); an M.E. in Chemical Engineering from University of Roorkee, India (1994); and a B.S. in Chemical Engineering from Aligarh Muslim University, India (1992). Attached as **Exhibit A** is my CV, which is incorporated by reference into this Report.

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8. I have authored over 500 research articles in peer-reviewed journals. These articles are frequently cited by other professionals.

c. Documents Reviewed and Considered

9. Attached as **Exhibit A** is the list of videos I reviewed and relied on when drafting this Report.
10. Attached as **Exhibits B** are documents I reviewed that are publicly available but were not produced in the arbitration.

II. RELEVANT BACKGROUND

On February 28, 2023, Tuesday, at 11:21 p.m., near the settlement of Evangelismos Tempon, Larissa, the electric passenger train INTERCITY (IC) 62, which was running a scheduled route on the route Athens - Thessaloniki, collided head-on with commercial train 63503, which was running the route Thessaloniki - Athens (Thriassio), resulting in the death of 57 passengers including train staff and at least 85 injured.

The passenger train was mistakenly directed by the Larissa stationmaster to the wrong track cruising in the opposite direction of the normal traffic conditions. As a result the passenger train was in a collision course with the freighter train.

The operator of the freighter train moments before the collision notices the oncoming passenger train exiting from a tunnel and applied the emergency brakes to stop the train. As a result of this action the 1st and 2nd locomotives of the freighter train veered off the tracks avoiding a head on collision with the passenger train. All three locomotives involved had no sign of fire and were found at different places in the accident site.

Immediately after the two locomotives veered off, a series of electric arcs were noticed. Those are also visible in one video clip (camera of Maliakos S.A.). Moments before the fireball started we also notice a cloud clearly rising over the accident site.

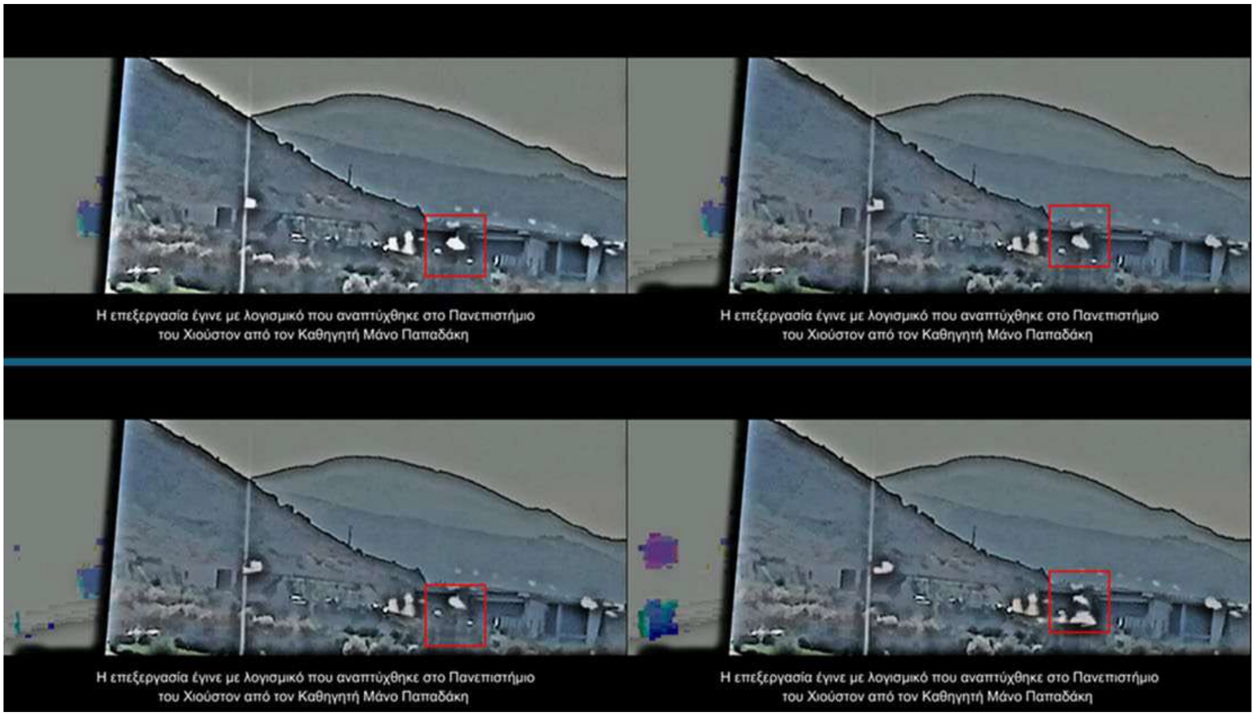

Figure 1. The rising vapor cloud shown in the red rectangles. On the bottom right panel there is fire below it (From Mr. Kokotsakis' report).

Then we have the development of the fireball. Using Solidworks we simulated the fireball. The simulation gave us its maximum volume to be 139987m^3. The fireball was not isotropic. Its biggest dimension was 113m because it was elongated by the passing through it of the first car of the passenger train followed by the café car. This length has been estimated from a camera located at a tunnel viewing the fireball at approximately 103 degrees angle with its longitudinal plane (Fig. 2). These measurements are not ours but have been provided to us by Mr. Kokotsakis' team. Using SolidWorks, this team developed a 3D model of the fireball.

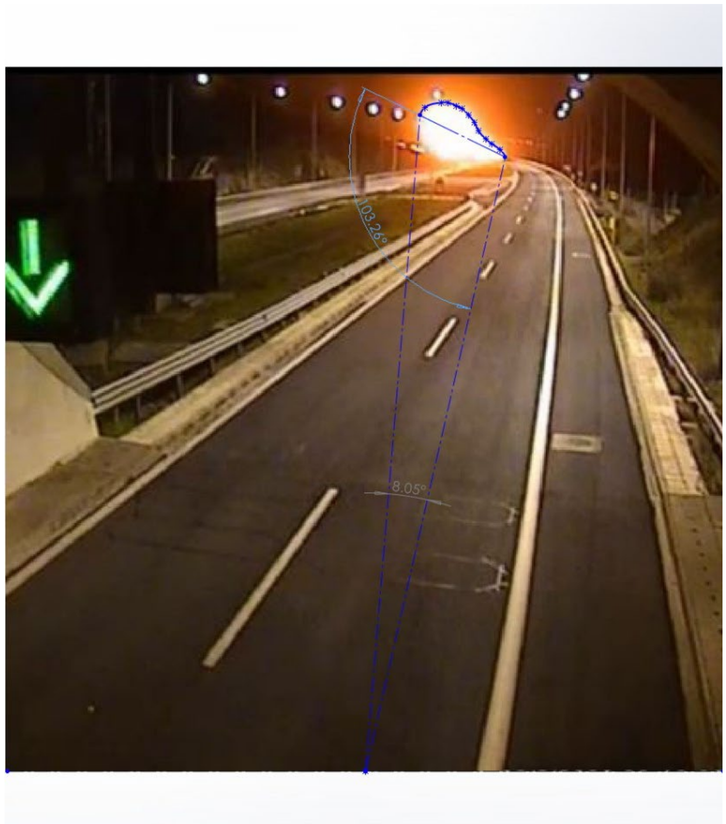

Figure 2. The triangle shows the calculation of the maximum length of the fireball. This is a frame extracted from one of the two videos in Exhibit A. The picture is extracted from Mr. Kokotsakis' report. The fireball maximum length as viewed from the Tempi 1 tunnel camera (located north of the accident site 750m away)

The SolidWorks simulation was cross correlated by Mr. Kokotsakis' team with the frames from the two videos listed in Exhibit A and was found to be in full agreement with its visual footprints in the videos (Fig. 3). The lifetime of the fireball was about 9.6 seconds.

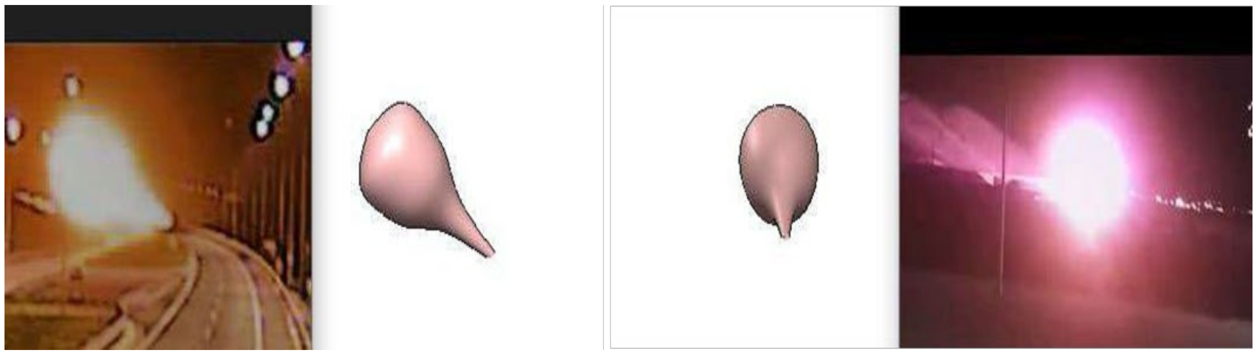

Figure 3. Comparison of the simulated fireball views with actual footage. The left is from the camera at the Tempi 1 tunnel exit the right one is from the campus of Maliakos S.A. The scale in the actual images and the the simulation is 1:1. The simulated fireball has been adjusted for the distance and angle of view for each of the two cameras.

A subsequent analysis with mass spectrometer of soil found traces of benzene (in 7 samples), toluene (in 4 samples) and xylene (in 7 samples), all three isomers of it. These findings are reported in the list of documents identified with Greek characters ΕΜΠ 12-2,3,6,10,14,19,20 (List in Exhibit A).

ANALYSIS

11. The detailed review of the video footage clearly indicates a fire accident (Fire Ball). The fire ball occurred after the collision in less than three seconds after the collision.
12. The Fire Ball is massive. It is hard to accurately estimate the dimension of the Fire Ball given lack of the data; however, visual analysis indicates it to be of 100+ meter diameter of non-isotropic shape.
13. Fire Ball of such magnitude is common in the industry involving hydrocarbons.
14. Fire Ball is also a commonly reported accident on the road and railway accidents involving hydrocarbons.
15. The temperature in the Fire Ball easily exceeds 1000ºC [depending upon the type of chemical and mixing].

16. Anything that come within the Fire Ball is most likely to be damaged severely and its exposure to human will cause fatality.
17. The Fire Ball in limited cases can generate overpressure [explosion condition]. However, the damage by overpressure is lower compared to heat load.
18. Fire Ball occurs when volatile hydrocarbon suddenly released in large quantity in open area of area that is covered with building and other obstructions often referred as semi-confined area, get well mix with air (forming flammable vapor cloud), and get ignited. The ignition led to a very fast rate of burning of the well mixed vapor cloud generate intense heat load.
19. In limiting conditions (when the burning vapor cloud is restricted within a confinement or obstruction), Fire Ball may create overpressure thus the shock wave.
20. The Fire Ball accident require three key elements: vapor cloud, high mixing, and ignition source. A road or railway accident often provide all three elements. The vapor cloud often comes from the light fuel such as Gasoline (petrol) collision provide sufficient turbulence to well mix the released vapors, and spark or heat provide source of ignition.
21. The Fire Ball is most prone to occur in lighter hydrocarbons, such as Gasoline, Jet Fuel, lighter aromatics (Benzene and their derivates), Butane, Propane,

III. <u>OPINIONS</u>

22. Considering the incident data and video footage, it is evident that the train was carrying chemicals, most likely lighter hydrocarbons.
23. The chemical analysis of the surrounding area and residue on the victims and damaged assets indicates the presence of Benzene, Toluene, and Xylene.
24. Benzene, Toluene and Xylene are lighter hydrocarbons and commonly used chemicals for range of applications including paints, cosmetics and others.
25. It is very likely that the freighter train was carrying Benzene, Toluene, and Xylene. Due to the impact caused by collision, these chemicals are released from the containers and form a vapor cloud.

26. The vapor cloud, well mixed with the air, caused the Fire Ball.
27. Hydrocarbon derivatives, such as high-viscosity oil and silicone oils, are thermally stable and used for lubricant and cooling purposes. When released, such oils will not cause Fireballs because they are low in volatile hydrocarbons and lower in flammability. High volatility and flammability are required to form vapor clouds, which burn at a relatively higher rate and cause Fire ball.
28. The Fire Ball is likely to be ignited by the close proximity of its formation source, which is the freight carriage. The video demonstrates how the Fire Ball evolved from the source and expanded outward.
29. The Fire Ball engulfed the passenger carriage area, causing severe damage and fatalities.
30. The damage to the surrounding assets (decolorization) and lethal burning fatalities confirm the presence and damage caused by the Fire Ball.

I reserve the right to amend this report upon receipt and review of additional or new information. If asked to give testimony, my testimony will be consistent with this Report.

Executed on July 24, 2024

Dr. Faisal Khan

EXHIBIT A

Videos we examined

OSE1.mp4 (από την κάμερα της κοινοπρξίας Μαλλιακός)

Fireball simulation overlaid.mp4 (παρήχθη απο την ομάδα Κοκοτσάκη)

600193_T1SB7-PTZ_2023_02_28.23_18_00_60_RC.avi (κάμερα αυτοκινητοδρόμου Αιγαίου)

EXHIBIT B

1. Fireball mathematical models and experimental data: A literature review. HSE UK, Research report 1185 (2022)
2. BLEV (FIREBALL) Theory and Validation, DNV, December 2023
3. Silicones, Chapter 8 in collection Reactive Polymers Fundamentals and Applications. http://dx.doi.org/10.1016/B978-1-4557-3149-7.00008-5, 2013 Elsevier Inc. All rights reserved.
4. Fire Ball accident: https://www.hazmatnation.com/news/massive-fireball-after-train-18-wheeler-collide-burns-down-barn-leaves-several-families-homes-heat-damaged/
5. Definition of Fire Ball https://www.aiche.org/ccps/resources/glossary/process-safety-glossary/fireball