TRACTOR TRAILER EXPLOSION

Benicia, CA
January 19, 1985

NFPA INTERNATIONAL

FIRE INVESTIGATIONS

NATIONAL FIRE PROTECTION ASSOCIATION

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NATIONAL FIRE PROTECTION ASSOCIATION
INTERNATIONAL

Summary Investigation Report

Highway Accident Involving Molten Sulfur Benicia, CA January 19, 1985

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In Cooperation with

Federal Emergency Management Agency/
United States Fire Administration

and

National Bureau of Standards/
Center for Fire Research

Note: Photographs referenced in the text are not included in the .pdf file.

ABSTRACT

Just before noontime on January 19, 1985, a truck pulling two tank trailers loaded with molten sulfur was involved in a collision on the southbound side of the Benicia-Martinez Bridge in Benicia, California. The truck/trailer combination jumped the center divider into oncoming traffic, striking a northbound truck. One of the tanks ruptured on impact, spilling its contents and spewing molten sulfur onto two other vehicles. Ignition of the molten sulfur occurred immediately.

The driver of the sulfur truck was pinned in the wreckage of his cab. Fire fighters were unable to extricate him from the cab before it was engulfed in fire, and the driver died. Two occupants of one of the northbound vehicles were sprayed with molten sulfur. Although they were able to escape from their vehicle, they were severely burned and one died four days later.

The Benicia Fire Department responded within five minutes of the accident and immediately initiated rescue and fire control operations. Back-up units were called in and a request for mutual aid was made shortly thereafter. Fire fighting operations lasted until about 4:00 p.m. Clean-up operations lasted until the following morning.

The following are considered the major factors in this incident:

- Detailed emergency response information on molten sulfur was lacking due to the fact that sulfur is not regulated as a hazardous material.
- There was some delay in responding to the incident due to traffic and to limited access to the bridge.
- There was difficulty in confirming the nature of the cargo.
- Visibility at the accident site was severely limited due to dense vapors of sulfur dioxide and due to fog.

INTRODUCTION

The National Fire Protection Association (NFPA) investigated the highway accident involving molten sulfur that occurred on the Benicia-Martinez Bridge in order to document and analyze the incident and factors that contributed to its development.

This study was conducted under a Major Fires Investigations Agreement between the Federal Emergency Management Agency/United States Fire Administration (FEMA/USFA), the National Bureau of Standards/Center for Fire Research (NBS/CFR), and the NFPA. The agreement, funded by FEMA/USFA, NBS/CFR and NFPA, provides for the investigation of technically significant fires by the NFPA Fire Investigations and Applied Research Division to document and analyze incident details and report lessons learned for life safety and loss prevention purposes.

NFPA was asked to conduct this on-site investigation by Hank A. Howard, Chief of the Benicia Fire Department. On January 28, 1985, Robert P. Benedetti, Senior Chemical Engineer for NFPA's Engineering Services Division, began a two and one-half day on-site investigation. This report is based on that investigation and subsequent analysis. The site survey, data collection, and interviews with fire department personnel were made possible through the cooperation of the Benicia Fire Department.

This report is another of NFPA's studies of fires having particularly important educational or technical interest. The information presented is based on the best data available during the on-site data collection phase and during the report development process. It is not NFPA's intention that this report pass judgment on, or fix liability for, the loss of life and property in this incident.

The assistance of the following Benicia Fire Department personnel is gratefully acknowledged: Chief Hank A. Howard, Deputy Chief Michael Tessier, Public Information Officer Joseph Thurin, Hazardous Materials Coordinator Richard Jones, Captain Chester Taylor and his entire crew, and Mr. Earl Book, Captain, Volunteer Forces.

Special thanks are due to Fire Fighters Michael Ellison and Scott Book for their work in providing maps and diagrams of the accident site; and to Fire Cadets William Youles, Jr. and James Collins for their photographs of the accident.

Finally, information and assistance obtained from the following individuals is deeply appreciated: Sergeant D. G. Freeman, California Highway Patrol; Mr. James Becker, National Transportation Safety Board; and Mr. Ronald Robinson, National Transportation Safety Board.

BACKGROUND

Benicia, California is a city of 20,000-plus population and 15.6 square miles, located about 45 miles northeast of San Francisco. It is situated in Solano County, on the north shore of Carquinez Strait, where the east end of the strait becomes Suisun Bay. The city extends northward from the strait back to some foothills which divide Solano County from the Napa Valley. Almost all of the residential area and all of the business district is within one and one-half miles of the strait.

A heavily industrialized area is located in the northeast quadrant of the city. This area includes an Exxon Company refinery and marketing terminal, a Huntway Company asphalt refinery, a Liquid Carbonic Company carbon dioxide distribution plant, and a number of general industry facilities and warehouses, most about 50,000 square feet in size. In this same general area are a railroad freight yard and a Class I waste disposal site, although the latter is beyond the city limits.

The city has a deepwater port along the strait. The port has a crude oil unloading dock, a petroleum product loading dock, and a coke loading facility that includes a storage silo. An automobile import-receiving yard is adjacent to the dock area. Petroleum pipelines run from the docks back to the refineries and a crude oil tank farm. Portions of these pipelines are buried underground.

The Benicia-Martinez Bridge is located just east of the deepwater port at the southeast tip of the city. A double-track railroad bridge belonging to the Southern Pacific Railroad parallels the Benicia-Martinez Bridge on its east side.

Two major highways run through the city. Interstate Highway 680 runs north from the Benicia-Martinez Bridge, between the shore of Suisun Bay

and the industrial area. Interstate Highway 780 runs west from the bridge towards Vallejo. Interstate 780 is the east-west connector between Interstate 680 and Interstate 80, about seven miles away. The interchange for these two highways is just north of the bridge.

The Benicia-Martinez Bridge runs northwest to southeast, carrying Interstate Highway 680 from Benicia to the city of Martinez, in Contra Costa County. There is a toll plaza at the Benicia end, about 300 feet north of the bridge abutment. Tolls are collected from northbound traffic only. The I-680/I-780 interchange begins just north of the toll plaza. It is estimated that there are as many as 30,000 trips daily across this bridge, many involving hazardous cargoes.

The Benicia-Martinez Bridge is paralleled to the east by a railroad bridge belonging to the Southern Pacific Railroad. This bridge carries two mainline railroad tracks and an 8-in. petroleum pipeline. The separation between the two bridges appears to be about 125 feet.

The Benicia-Martinez Bridge is about one mile long and its deck is about 50 feet wide. It carries two lanes of traffic in each direction, the northbound and southbound sides separated by a 3-foot high concrete barrier, commonly referred to as a "Jersey" barrier. This barrier is fixed in place and is topped by a chain link fence about 18 inches high. The bridge construction is concrete deck on steel truss and beam. Each section of the bridge is supported by concrete piers. The bridge deck is paved with asphalt aggregate. There are hydrants at each end of the bridge and a 10-in. fire main runs beneath the bridge deck. This main has feed standpipes at each end and supply risers up to the bridge deck at intervals along the length of the bridge. The feed standpipes are fed by direct connection to the hydrants.

At the north end of the bridge, an access road runs from the breakdown lane of the southbound side, down and underneath the bridge deck and back up to the northbound side.

The bridge authority which controls the Benicia-Martinez Bridge also controls the Carquinez (twin) Bridges in Vallejo. No emergency equipment is provided by the bridge authority other than a single wrecker which shuttles between the two bridges. Also, there reportedly is no direct radio link between the two bridges or between either bridge and the wrecker. Apparently, all communication is routed through the region's bridge authority headquarters in Oakland, CA.

A permit is necessary to ship the following restricted cargoes across the bridge: Corrosives, Class A and Class B Explosives, and certain Class C Explosives. All other materials are under no restriction.

With respect to the interchange just north of the toll plaza, it is important to note that traffic moving south on Interstate 680 travels downgrade to pass under two bridge decks stacked one above the other (the connector between the northbound side of the bridge and I-780 westbound and the connector between I-780 eastbound and I-680 northbound), then upgrade onto the bridge approach. It is at the top of this upgrade that traffic moving south on I-680 must merge with traffic moving from I-780 eastbound onto the bridge.

Due to the amount of traffic handled by this bridge and congestion, caused by rush-hour traffic and accidents, the Benicia Fire Department and the Contra Costa County Consolidated Fire District have agreed to a plan whereby Benicia handles the toll plaza and the southbound lanes all the way to the Martinez end and Contra Costa handles the northbound lanes up to the toll plaza. (This arrangement accommodates Contra Costa's policy not to run apparatus against the normal direction of travel.)

The Benicia Fire Department is a part paid/part volunteer department. The officer ranks include a chief, a deputy chief, a fire marshal, and a hazardous materials coordinator. The paid force consists of three shift captains, twenty-eight fire fighters, and a paramedic. The volunteer force consists of

a captain and thirty-five fire fighters. One of the paid fire fighters serves as the public information officer. Several fire fighters are also emergency medical technicians.

The Department has three well-equipped stations. Apparatus consists of two ladder trucks, five engines, a pumper, three 4-wheel drive brush trucks (Dodge power wagons), a water tender and 1000-gallon tanker, and three command vehicles. Special equipment includes an ambulance, a boat and trailer, a trailer-mounted air compressor with generator and floodlights, and a trailer with foam equipment and foam concentrate supply.

The Department has outfitted a station wagon as a hazardous materials response unit. This unit has hand tools, combustible gas detectors (with oxygen and H_2S capability), two totally encapsulated butyl rubber suits, leak repair plugs and accessories, and spill neutralization chemicals. Reference materials are current and extensive. Also, the Department has an on-line computer link with HAZARDLINE, an on line information service that provides extensive data on hazardous materials and chemicals. All Department personnel receive ongoing hazardous materials training.

Weather conditions at 12:00 noon on the day of the incident were:

Temperature:	38.5°F
Wind:	60° ENE @ 5 MPH
Humidity:	100%
Dewpoint:	40°F
Ceiling:	300′ (Fog)
Sky:	Obscure
Visibility:	1 Mile at Ground Level

Note: By 1300 hrs, the wind shifted from 60°ENE to 180°S. By 1400 hrs, both the temperature and the dewpoint had increased to 41.5°F and the wind had shifted back to 60°ENE.

THE INCIDENT

At approximately 11:50 a.m. on January 19, 1985, a tractor-truck pulling two tank-trailers (Vehicle 1), each loaded with 27,000 pounds of molten sulfur, collided with a Chevrolet Camaro (Vehicle 2) as both vehicles headed onto the southbound lanes of the Benicia-Martinez Bridge. The truck had just left the Exxon Company refinery about 1 1/2 miles north of the bridge and was headed to a Stauffer Chemical Company plant in Martinez, a trip of about five miles. The truck was approaching the bridge from Interstate Highway 680-South; the Camaro was approaching from Interstate Highway 780-East. (See Accident Site Diagram, Figure 1, Appendix A; refer to Appendix B for vehicle descriptions.)

It appears that both vehicles were changing lanes and crossed each other's path. In so doing, the right front corner of the tractor-truck struck the left rear of the Camaro. One eyewitness claimed that he heard the truck downshift, then heard the screeching of brakes. He then saw and heard the tanks hit and roll over the center divider. He did not hear an initial contact. The downshifting is consistent with the fact that the truck had to ascend a slight grade as it approached the bridge.

The initial contact between the two vehicles seems to have occurred just south of the toll booths. The Camaro spun out of control and came to rest against the south wall of the bridge. The truck careened along the bridge approach lanes, then struck and vaulted over the center divider into oncoming traffic. Both vehicles travelled up to 250 feet from the point of initial contact. (Point "X" on the Accident Site Diagram, Figure 1.)

The tractor-truck ended upside down, straddling the center divide.. (See Photo 1.) The driver was pinned in the wreckage of the cab. The two tank trailers vaulted completely over the divider into oncoming traffic, one of them striking a northbound Mack truck (Vehicle 3) pulling an empty two-stall

horse trailer. The horse trailer was sheared from the truck and knocked down the embankment between the toll plaza approach lanes and the access road. The Mack truck was also knocked off the road and it struck a northbound Chevrolet Camaro (Vehicle 4) before coming to rest on the embankment. (See Photo 2.) The Mack truck immediately caught fire. Both occupants escaped unharmed.

The northbound Camaro came to rest across the travel lanes, against the curbing at the end of the bridge abutment. The three occupants (two adults and a child) escaped unharmed. A fifth vehicle was also involved: a northbound Chevrolet El Camino (Vehicle 5) was struck and pinned against the wall of the bridge by one of the tank trailers. The middle-aged couple in this vehicle escaped from their vehicle, but were both badly burned.

When the two tank trailers hit the pavement on the northbound side, one of them ruptured, spewing molten sulfur onto the three northbound vehicles and onto the pavement. According to eyewitnesses, ignition occurred immediately after the tank ruptured. As explained above, the occupants of the Camaro were not harmed, while those of the El Camino were badly burned. This may be due in part to the fact that the driver of the El Camino had rolled down his window to pay the toll. Both occupants were splattered with molten sulfur. The driver ran down the embankment and collapsed. His wife ran towards the toll booths where she was assisted by two of the attendants.

Fire Department Response

At the time of the incident, all on-duty Benicia Fire Department personnel were attending a training session at Station No. 2, about five miles from the bridge. The Bridge Authority first reported the incident to Benicia's dispatch center at 11:51 a.m. Because this initial report was for a "vehicle accident," an engine, an ambulance , and two police cruisers were directed to respond. Within a minute's time, Engine 1 (officer, engineer, and fire

fighter) and PM-71 (paramedic and fire fighter/EMT) were en route. The police units arrived at the scene at 11:55 and began to relay information.

The accident completely stopped all bridge traffic and Engine 1 and PM-71 encountered heavy traffic about one-half mile from the bridge. By this time, they had been notified of a victim trapped in a vehicle, a victim at the toll booths, a victim lying on the embankment next to the bridge approach, and a "caustic" fuel involved. The officer-in-charge requested an additional engine, additional ambulances, and a first alarm.

Engine 1 and PM-71 arrived on the bridge at 11:59 a.m. and were immediately directed to the northbound side of the toll plaza by the police. The paramedic was left to attend to the victim at the toll booth and the two fire units moved to the northbound side via the access road. Once on the northbound side, they found a second victim lying on the embankment between the bridge approach, the access road and the burning Mack truck (Vehicle 3). Heavy smoke and fire were also showing up on the bridge deck. While the officer-in-charge evaluated the situation, the fire fighter and the EMT tended the victim. The engineer laid a 2 1/2-in. supply line to a nearby hydrant and attacked the truck fire (Vehicle 3) with a 1 3/4-in. preconnected line. He was able to extinguish this fire before the supply line was burned through by molten sulfur flowing along the edge of the road. The officer-in-charge notified the dispatch center that there were 3 or 4 vehicles on fire up on the bridge and that a chemical had been spilled. He requested a second alarm.

Engine 3 reported on the scene at 12:02 p.m. and was directed to assist the victim at the toll booth until she could be sent to a hospital. After this task was completed, Engine 3 was directed to proceed up the southbound lanes of the bridge and to begin suppression operations. They set up a foam eductor and were able to extinguish fires in the trailer hauled by Vehicle 4

and in Vehicle 5 before running out of water. Visibility was still so poor at this time that they could not see the sulfur tank trailers or the tractor that had been pulling it.

By this time, the fire fighters on the northbound side were told of a third victim trapped in a vehicle up on the bridge. One of the fire fighters went up onto the bridge and checked Vehicles 4 and 5 for any victims. He then proceeded to the tractor-truck which had been pulling the tank trailers. This truck (Vehicle 1) was upside-down, straddling the concrete divider. The driver was hanging upside-down in the cab, pinned between the seat and the dash. The driver was fully conscious, calm, and had only minor cuts and bruises. The fire fighter ran back to PM-71 to get a resuscitator. He requested that PM-71 be moved to the southbound side and that hose lines be run down the southbound side to protect Vehicle 1. As he returned with the resuscitator, he slipped in the molten sulfur and fell. He was able to get up and out of the area, but his turnout gear was ignited by the burning sulfur. He took off the gear, went back into the area and placed the face mask from the resuscitator on the driver. At this time the driver told him the tanks held molten sulfur. He tried to extricate the driver, but was driven from the area by the encroaching fire. Tires and fuel tanks began exploding, and rescuers could not reach the driver before the cab became totally involved in fire. The driver died in the ensuing fire.

By 12:20 p.m., a general alarm had been sounded. The Benicia fire chief responded, assumed command of the incident and established a command post north of the toll booths. The Benicia Hazardous Materials Unit had also arrived, and two fire fighters donned totally encapsulated chemical protective suits. They entered the area to determine the conditions of the two tanks and to verify the nature of the cargo. One tank was totally destroyed, and the

other tank was leaking molten sulfur through several tears . They were not able to immediately verify the nature of the cargo. Because of heat and exertion, both fire fighters had to withdraw and return twice before finding the driver's log book, one and one-half hours after the initial alarm. The fire department was then able to contact the trucking company and verify the cargo.

Throughout this time period, additional fire units were responding from Benicia and from Contra Costa County Consolidated Fire District (from the Martinez end of the bridge). As shown in Figure 1, Benicia Engine 5 was able to run a 4-in. supply line from a hydrant to a manifold which was used to supply Engine 3, OES 117, and the Contra Costa units. Contra Costa was able to provide three engines and a truck company which commenced operations from the south side of the accident scene.

The fire chief had also ordered the dock area evacuated as well as areas one-half mile down-wind of the bridge. An ambulance staging area had been designated and mutual aid units were on hand, held in reserve.

The fire was declared under control at 12:47 p.m. and final overhaul was completed at 2:40 p.m. The flow of sulfur from the one intact tank could not be plugged, but was kept under control by applying hose streams to the tears. (See Photo 3.) Accident investigation work by California Highway Patrol lasted until 11:30 p.m. Clean-up operations then began and the intact trailer, with 600 gallons of sulfur still on-board, was removed. Clean-up operations lasted until 4:00 p.m. the next day.

ANALYSIS

The first question that arises in analyzing this incident is: How did a relatively minor collision result in such a disaster? As described in Appendix B, each tank had a capacity of about 3,200 gallons. Because of the weight of the molten sulfur and the maximum legal gross vehicle weight of 80,000 pounds, each tank was carrying about 1,835 gallons, 57 percent of capacity. The tanks did not have internal baffles. When the initial collision occurred, both vehicles were changing lanes and it is safe to assume that both drivers instinctively steered, away from each other. Such an abrupt change of direction could cause the molten sulfur in both tanks to surge to one side. The resultant of the various forces acting on the tank trailers and the cargo of molten sulfur was most likely more than the driver could control. When the truck and trailers hit the center divider, the molten sulfur was probably surging in that direction and the momentum of this surge carried the tanks over the wall.

The primary factor in the subsequent development of the incident is the unregulated nature of the cargo. Molten sulfur, as explained in Appendix C, is not regulated as a hazardous material by the U.S. Department of Transportation. Yet it behaved, in this incident, just like a regulated hazardous material and presented to emergency response personnel a set of conditions to which they were not accustomed. The injuries sustained by the victims were not typical burns. The molten sulfur adhered to skin, hair, and clothing, thus intensifying the burn injury. The sulfur dioxide gas produced by the burning sulfur was not easily carried away by the fire plume; it stayed at ground level. (See Photos 4, 5, & 6.) This gas also produced some discomfort to emergency response personnel because it combines with skin moisture and moisture in the respiratory tract to produce a mild acidic solution.

The first arriving company officer and the fire chief were concerned about the nature of the material. If molten sulfur were a regulated hazardous material, the tanks would have been placarded and paperwork in the cab would have provided emergency response personnel with immediate information confirming the identity of the cargo as given by the driver. Additionally, emergency response guides may have provided some helpful information in the early stages of this incident. Finally, it must be recognized that a person's behavior in an emergency is increasingly conservative, the greater the number of unknown factors. For example, on-scene fire fighters did not know whether a BLEVE could occur or whether the material itself was subject to an explosive reaction.

The question of the identity of the cargo raises the side issue of how well the available emergency response information addressed the hazards presented by this incident. Although the information contained in NFPA 49, Hazardous Chemicals Data, and the DOT Emergency Response Guidebook are fairly complete, neither specifically indicates the irritating nature of sulfur dioxide or its tendency to hover at grade level. Finally, the unregulated nature of this cargo has already raised the question, at least in the minds of those directly involved, of how many other unregulated materials may present unusual hazards in a fire or spill situation.

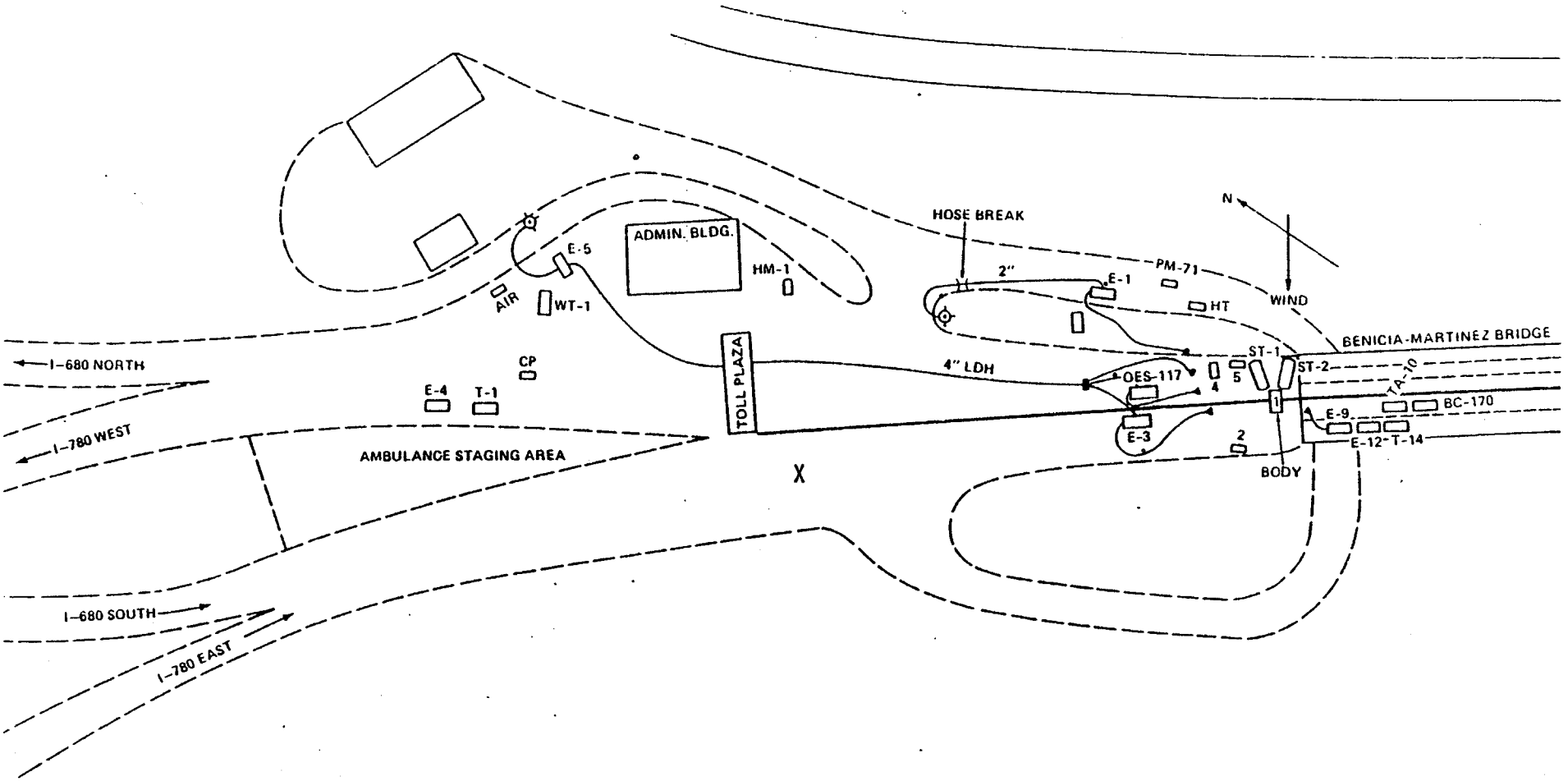
Another factor in this incident was the delay, albeit minor, in the arrival of responding units due to traffic and limited access to the bridge. It is imperative that local officials responsible for developing emergency response plans recognize the need for alternate routes to potential accident areas and anticipate the problems that may develop from traffic or adverse weather conditions. In this incident, the Benicia Fire Department was fortunate in only having to contend with the traffic conditions of a typical Saturday morning. The Benicia-Martinez Bridge is a major north-south access

route to and from the San Francisco Bay area, subject to heavy commuter traffic each morning and afternoon. Had this incident occurred at 5:00 p.m. on a weekday, the scale of injuries and destruction would have increased dramatically.

The following are considered the major factors in this incident:

- Detailed emergency response information on molten sulfur was lacking due to the fact that sulfur is not regulated as a hazardous material.
- There was some delay in responding to the incident due to traffic and to limited access to the bridge.
- There was difficulty in confirming the nature of the cargo.
- Visibility at the accident site was severely limited due to dense vapors of sulfur dioxide and due to fog.

APPENDICES



APPENDIX A

FIGURE 1

LEGEND
FIGURE 1

I. Vehicle Involved in Accident

1	1974 White Tractor-Truck
2	1974 Camaro
3	1959 Mack Tractor-Truck
4	1967 Camaro
5	1971 El Camino
ST-1, ST-2	Sulfur Tank Trailers
HT	Horse Trailer

(See Appendix B for more detailed descriptions.)

II. Benicia Fire Department Apparatus

E-1, E-3, E-4, E-5	Engines
OES-117	Pumper
T-1	Ladder Truck
PM-71	Paramedic Ambulance
HM-1	Hazardous Materials Unit
CP	Command Vehicle
WT-1	Water Tender
Air	Compressed Air Unit

III. Contra Costa County Apparatus

E-9, E-12	Engines
T-14	Ladder Truck
TA-10	Water Supply
BC-170	Command Vehicle

APPENDIX B

Descriptions of Vehicles Involved

(Note: Numbers correspond to site diagram)

1. Truck/Tank Trailer Combination. This was a 1974 White Motors Corp. 6-wheeled tractor pulling a semi-tank trailer/tank trailer combination. Each trailer unit is about 23 feet long, making the full rig just under the maximum 65-foot length allowed by California. Each tank was double-shelled, the inner tank being 3/8-in. aluminum alloy and the outer jacket of light-gage aluminum. The 1 1/2-in. to 2-in. interstitial space was insulated with either mineral wool or glass fiber insulation. The tanks were <u>not</u> designed according to DOT specifications and did not have inner baffles. Total capacity of each tank was about 3,200 gallons.

   The legal gross vehicle weight for this combination was 80,000 pounds. On the day of the accident, the gross vehicle weight was 80,640 pounds; the sulfur cargo totalled 54,730 pounds, evenly divided between the two tanks. Since molten sulfur has a mean density of 14.9 pounds per gallon, total gallonage of cargo is about 3,675 gallons. Thus, each tank carried roughly 1,835 gallons, or less than 60 percent filled.

   The tractor was completely destroyed by collision and fire, almost to the point of being unrecognizable. The ruptured tank was, of course, a total loss. The second tank suffered collision damage and several shell tears.

2. 1974 Chevrolet Camaro. This vehicle was involved in the initial collision. It was heading from I-780 eastbound onto the southbound side of the bridge. It suffered minor damage to its left rear bumper, where it was struck by Vehicle 2.

3. 1959 Mack Tractor. This 6-wheel tractor was pulling an empty two-stall horse trailer by means of a tow-ball mounted beneath the end of the truck frame. It was heading north on the bridge and was approaching the toll plaza when it was struck by one of the tank trailers. It caught fire immediately after impact and was completely gutted. Impact damage was also considerable.

4. 1967 Chevrolet Camaro. This automobile was pulling a small flat-bed trailer and was traveling just ahead of the 1959 Mack described above. It was apparently struck by this same truck as the latter carreened off the bridge and down the embankment to the right of the toll plaza approach. This vehicle suffered relatively minor impact damage and no fire damage. However, it was completely covered by solidified sulfur sprayed onto it by the ruptured tank.

5. 1971 Chevrolet El Camino. This sport pick-up was traveling behind the 1959 Mack described above. It apparently drove into the path of one of the tank trailers and was wedged against the bridge deck side wall by the tank. This vehicle suffered little impact damage but, of course, was totally engulfed in fire.

APPENDIX C

Hazardous Materials Regulations

Regarding Sulfur

According to the Hazardous Materials Table in Part 172.101 of Title 49 of the Code of Federal Regulations, sulfur (solid) is classified as an "Other Regulated Material - Class C." There is no listing for molten sulfur. Part 173.500 defines Other Regulated Material - Class C as "... a material which has other inherent characteristics not described as an ORM-A or ORM-B but which make it unsuitable for shipment unless properly identified and prepared for transportation."

The Hazardous Materials Table listing for sulfur contains references to Parts 173.505 and 173.1080. Part 173.505 provides for an exemption from the regulations for quantities not exceeding 25 pounds in one package and Part 173.1080 refers specifically to transportation by water.

Other Regulated Materials are not subject to labeling or placarding requirements, as stated in Parts 172.400(b)(8) and 172.500(b)(2). However, the Hazardous Materials Table does state that, when transported by vessel, sulfur must be stored as a flammable solid and must be segregated from oxidizing agents.

Referring to the Optional Hazardous Materials Table in Part 172.102 of Title 49, which applies to international shipments, there are found two listings of interest:

"Sulphur, lump or powder UN 1350" and

"Sulphur, molten UN 2448"

Both are classified as "Flammable Solids" and must be labeled and placarded as such.

APPENDIX D

Properties of Sulfur and Sulfur Dioxide

I. Sulfur

Sulfur is a chemical element, normally a solid, having the following properties:

Physical State:	Yellow solid or powder or yellow-brown molten liquid
Molecular Weight:	32.06
Melting Point:	119°C
Boiling Point:	444°C at atmospheric pressure
Bulk Density:	Solid - 75 to 87 lbs. per cu. ft. Molten- 112 lbs per cu. ft.
Vapor Pressure:	0.11 mm Hg @ 140°C
Solubility in Water:	Insoluble
Minimum Explosive Concentration of Dust:	0.035 ounces per cu. ft.
Flash Point (molten):	Pure - 188°C Impure - As low as 168°C
Autoignition Temperature:	220-232°C

Pure sulfur is odorless, but traces of hydrocarbon impurities may give sulfur an oily or hydrogen sulfide (rotten egg) odor. Also, hydrocarbon impurities may give sulfur an orange, tan, or brown color. Sulfur is moderately reactive with oxidizing agents, alkalis, and alkaline materials. Mixtures of sulfur with chlorates, nitrates, and other strong oxidizing agents may be explosive. Sulfur is easily ignited by spark and flame and burns with a lazy, purple flame that is difficult to see in bright daylight. It burns to produce sulfur dioxide (see Appendix D, II).

Sulfur is often shipped in the molten state, at a temperature anywhere between 150°C to 200°C. In the molten state, sulfur is a viscous straw-colored or dark yellowish brown liquid.

(Reference: - Dean, J. A.: Lange's Handbook of Chemistry; 12th Edition; McGraw-Hill; New York; 1979.

- Masterton, W. L. et al; Chemical Principles; 5th Edition; College Publishing; Philadelphia, 1981.)

II. Sulfur Dioxide

Sulfur dioxide is a gaseous chemical compound that is produced by burning sulfur. It is a highly irritating, colorless gas that is easily liquefied. Its properties are as follows:

Physical State:	Colorless gas or colorless liquid
Molecular Weight:	64.06
Boiling Point:	-10°C (14°F)
Vapor Density:	2.26 (Air = 1.0)
Solubility in Water:	Completely soluble

Sulfur dioxide has a characteristic, pungent odor and is intensely irritating to the eyes, throat, and upper respiratory tract. It will combine with the moisture in the respiratory system to produce a weak acid that causes throat irritation, coughing, chest constriction and tearing and burning of the eyes. A concentration of 150 ppm (parts per million) can be endured for only a few minutes and any concentration above this level causes suffocation.

Sulfur dioxide is noncombustible; it poses no fire hazard.

(Reference: - Dean, J. A.: Lange's Handbook of Chemistry; 12th Edition; McGraw-Hill; New York; 1979.

- Masterton, W. L. et al; Chemical Principles; 5th Edition; College Publishing; Philadelphia, 1981.)

III. Emergency Response Information

Emergency response information from the following sources is attached:

- NFPA 49-1975, Hazardous Chemicals Data, National Fire Protection Association, Quincy, MA

- Emergency Response Guidebook, U.S. Department of Transportation, Washington, D.C.

GUIDE 32

POTENTIAL HAZARDS

FIRE OR EXPLOSION

Flammable/combustible material; may be ignited by heat, sparks or flames.
May burn rapidly with flare-burning effect.

HEALTH HAZARDS

Fire may produce irritating or poisonous gases.
Contact may cause burns to skin and eyes.
Runoff from fire control or dilution water may cause pollution.

EMERGENCY ACTION

Keep unnecessary people away; isolate hazard area and deny entry.
Stay upwind; keep out of low areas.
Wear self-contained (positive pressure if available) breathing apparatus and full protective clothing.
FOR EMERGENCY ASSISTANCE CALL CHEMTREC (800) 424-9300.
If water pollution occurs, notify appropriate authorities.

FIRE

Small Fires: Dry chemical, sand, water spray or foam.
Large Fires: Water spray, fog or foam.
Move container from fire area if you can do it without risk.
Cool containers that are exposed to flames with water from the side until well after fire is out.
For massive fire in cargo area, use unmanned hose holder or monitor nozzles; if this is impossible, withdraw from area and let fire burn.
Magnesium Fires: Use dry sand, Met-L-X powder or G-1 graphite powder; do not use water.

SPILL OR LEAK

Shut off ignition sources; no flares, smoking or flames in hazard area.
Do not touch spilled material.
Small Dry Spills: With clean shovel, place material into clean, dry container and cover; move containers from spill area.
Large Spills: Wet down with water and dike for later disposal.

FIRST AID

Move victim to fresh air; call emergency medical care.
In case of contact with material, immediately flush skin or eyes with running water for at least 15 minutes.
Remove and isolate contaminated clothing and shoes at the site.

LIFE HAZARD: Eye and respiratory irritant. High concentrations produce anesthetic effects, and prolonged exposure to high concentrations produces systemic effects.

PERSONAL PROTECTION: Wear self-contained breathing apparatus; wear goggles if eye protection not provided.

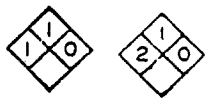
FIRE FIGHTING PHASES: In advanced or massive fires, fire fighting should be done from a safe distance or from a protected location. Use dry chemical foam, or carbon dioxide. Water may be ineffective (see Explanatory), but water should be used to keep fire-exposed containers cool. If a leak or spill has not ignited, use water spray to disperse the vapors. If it is necessary to stop a leak, use water spray to protect men attempting to do so. Water spray may be used to flush spills away from exposures. Styrene monomer vapors are uninhibited and may form polymers in vents or flame arresters of storage tanks, resulting in stoppage of vents.

USUAL SHIPPING CONTAINERS: Glass bottles, 1- to 5-gallon cans, 55-gallon metal drums, tank trucks, tank cars, tank barges.

STORAGE: Protect against physical damage. Outside or detached storage is preferable. Inside storage should be in a standard flammable liquids storage room or cabinet. The monomer must be checked at least weekly to determine inhibitor and polymer content if the material is being stored for any period of time in excess of 30 days at 90° F. Separate from oxidizing materials.

REMARKS: Electrical installations in Class I hazardous locations, as defined in Article 500 of the National Electrical Code, should be in accordance with Article 501 of the Code. If explosionproof electrical equipment is necessary, it shall be suitable for use in Group D. See Flammable and Combustible Liquids Code (NFPA No. 30), National Electrical Code (NFPA No. 70), Static Electricity (NFPA No. 77), Lightning Protection Code (NFPA No. 78), Fire-Hazard Properties of Flammable Liquids, Gases and Volatile Solids (NFPA No. 325M), and Chemical Safety Data Sheet SD-37 (Manufacturing Chemists' Association, Inc.).

SULFUR S_8



Nonfire Fire

DESCRIPTION: Yellow crystals, powder or solid.

FIRE AND EXPLOSION HAZARDS: Easily ignitible, combustible solid. Dust or vapor forms explosive mixtures with air. Flash point is 405° F., ignition temperature, 450° F., and melts at 234° F. Hazardous in contact with oxidizing materials, forming explosive mixtures.

LIFE HAZARD: Burning sulfur produces toxic sulfur dioxide gas.

PERSONAL PROTECTION: In fire conditions wear self-contained breathing apparatus.

FIRE FIGHTING PHASES: Use water spray; avoid straight streams which will scatter molten sulfur and dust. Small fires may be extinguished with sand or additional sulfur.

USUAL SHIPPING CONTAINERS: As a solid, in paper or jute bags, boxes, barrels, trucks and rail cars; also molten in tank trucks, rail cars and barges.

STORAGE: Protect against physical damage. Store in cool, well-ventilated place. Separate from chlorates, nitrates and other oxidizing materials. Guard against dust accumulation or aspiration of dust into air.

REMARKS: Electrical installations in Class I hazardous locations, as defined in Article 500 of the National Electrical Code, should be in accordance with Article 501 of the Code; and electrical equipment should be suitable for use in atmospheres containing sulfur vapors. Electrical installations in Class II hazardous locations, as defined in Article 500 of the National Electrical Code, should be in accordance with Article 502 of the Code; and electrical equipment should be suitable for use in atmospheres containing sulfur dust. See Fire-Hazard Properties of Flammable Liquids, Gases and Volatile Solids (NFPA No. 325M), Standard for the Prevention of Sulfur Fires and Explosions (NFPA No. 655), and Chemical Safety Data Sheet SD-74 (Manufacturing Chemists' Association, Inc.).

SULFUR DIOXIDE SO_2

DESCRIPTION: Highly irritating, colorless gas; liquid at temperatures below 14° F.

FIRE AND EXPLOSION HAZARDS: Noncombustible. Will extinguish fire.

LIFE HAZARD: Highly toxic. Extremely irritating to eyes and respiratory tract.

PERSONAL PROTECTION: Wear self-contained breathing apparatus; wear goggles if eye protection not provided.

FIRE FIGHTING PHASES: Stop flow of gas; keep cylinders and other vessels cool with water.

USUAL SHIPPING CONTAINERS: Pressure cylinders, from 5 to 150 pounds, one-ton cylinders, pressure tank cars.

STORAGE: Protect against physical damage, store outdoors or in a well-ventilated area of noncombustible construction.

REMARKS: See Chemical Safety Data Sheet SD-52 (Manufacturing Chemists' Association, Inc.).

SULFURIC ACID H_2SO_4

DESCRIPTION: Colorless (pure) to dark brown, oily, dense liquid.

FIRE AND EXPLOSION HAZARDS: Not flammable but highly reactive and capable of igniting finely divided combustible materials on contact. Reacts violently with water and organic materials with evolution of heat. Extremely hazardous in contact with many materials, particularly carbides, chlorates, fulminates, nitrates, picrates, powdered metals and other combustible materials. Attacks many metals, releasing hydrogen.

LIFE HAZARD: Causes severe, deep burns to tissue; very corrosive effect. Avoid any contact.

PERSONAL PROTECTION: Wear full protective clothing.

FIRE FIGHTING PHASES: Fires involving small amount of combustibles may be smothered with suitable dry chemical. Use water on combustibles burning in vicinity of this material but use care as water applied directly to this acid results in evolution of heat and causes splattering.

USUAL SHIPPING CONTAINERS: Glass bottles and carboys, metal barrels or drums with or without linings, tank trucks, tank cars, tank barges.

STORAGE: Protect against physical damage and water. Separate from carbides, chlorates, fulminates, nitrates, picrates, powdered metals and combustible materials.

REMARKS: See Chemical Safety Data Sheet SD-20 (Manufacturing Chemists' Association, Inc.).

SULFURIC OXYCHLORIDE

See SULFURYL CHLORIDE

SULFUR MONOCHLORIDE S_2Cl_2

DESCRIPTION: Amber to yellowish-red, oily, fuming liquid with a penetrating odor.

FIRE AND EXPLOSION HAZARDS: Combustible. Flash point, 245° F. Autoignition temperature, 453° F. Decomposes on contact with water.

LIFE HAZARD: Causes burns. Vapors irritating. Avoid contact of liquid and vapors with eyes, skin or clothing.

PERSONAL PROTECTION: Wear self-contained breathing apparatus; wear goggles if eye protection not provided.