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FIRES IN TRANSPORTATION

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Abstract

The National Transportation Safety Board is an independent federal agency dedicated to improving transportation safety. The Safety Board investigates all modes of transportation accidents, including pipeline accidents. Fires frequently occur in accidents as causal or as a result of the accident. Various accidents investigated by the National Transportation Safety Board are reviewed that demonstrate the need to improve fire safety in transportation. Improvements in fire safety can be achieved through improved material performance, better egress from transportation systems, better fire fighting techniques and better communications.

INTRODUCTION

The National Transportation Safety Board, the "Safety Board" is mandated by Congress in Public Law 93-633, cited as the "Independent Safety Act of 1974," to investigate transportation accidents in all transportation modes. The transportation modes include aviation, rail, marine, highway, and pipeline. The purpose of the Safety Board is to improve transportation safety in these various modes, and carries out its congressional mandate by conducting accident investigations and special safety studies, and formulating safety recommendations to improve transportation safety.

The Safety Board is well known in the aviation community as a result of its investigations of major aviation accidents. However, it is not as well known that the Safety Board often is the lead investigative agency in other transportation modes. For example, the Safety Board investigated the fire and explosion that resulted from the release of hydrocarbon gases from a salt storage dome in Brenham, Texas in 1991. The Safety Board is also involved in space accidents/incidents and played a major role in the investigation of the Challenger accident. The Safety Board has no regulatory authority, but its recommendations carry considerable persuasive merit within the transportation industry.

Although the occurrence of fire as the initiating factor in transportation accidents is infrequent, it does occur. However, the most frequent cause of fires in transportation accidents is the release of fuel and the subsequent ignition of this fuel due to various ignition sources in a collision dynamics. Survivable accidents in which a fire occurs may place unusual demands on both the materials inside the passenger compartment and unusual demands on the passengers themselves if they are to survive. In some accidents the ignition of large quantities of fuel prevents passengers from escaping an otherwise survivable accident. When ignited fuel vapors or mist enters the passenger compartment the flammability of the interior materials may make little difference in survivability. Even when the fuel does not get directly into the passenger compartment the exterior fire may be very rapid, intense, and spread quickly into the cabin area and subject the interior materials to a very intense fire.

FIRE HAZARDS IN MARINE TRANSPORTATION

Safety, particularly fire safety, of U.S. and foreign-flag passenger vessels in U.S. cruise trade has been of particular concern to the Safety Board for at least a decade. During the period of 1979 through 1992, the Safety Board investigated 16 foreign-flag passenger ship accidents operating from U.S. ports that carry mainly U.S. citizens. Eleven of these accidents involved fires. Investigations of these accidents identified numerous fire safety issues that include; (1) inadequate fire fighter training of crewmembers, (2) inadequate lifesaving equipment, (3) open fire doors, (4) inadequate inspection and maintenance of fire extinguishing equipment, (5) crew language barriers, (6) lack of automatic shutdown of ventilation equipment in the event of a fire, and (7) other fire protection problems. As a result of these investigations, the Safety Board recommended that current international standards (established by the International Maritime Organization, ISO) for structural fire protection, sprinkler installations, smoke/fire detection systems, crew qualifications, emergency drills, and crew language requirements be upgraded to ensure the safety of passengers. These accidents generated enough concern to warrant two special studies on passenger vessel safety, one in 1979 and one in 1993.[1-2] The need for the more recent study[2] was highlighted by the fire on board the Bahamian passenger ship SCANDINAVIAN STAR on April 7, 1990, in which 158 people lost their lives.[3] The Safety Board had investigated a previous fire on the SCANDINAVIAN STAR in March 15, 1988.[4] Two additional examples of fires on cruise ships illustrate the fire safety hazards on these ships.

On the evening of March 9, 1984, a fire was discovered in a room occupied by two crewmen aboard the Bahamian registered cruise ship SCANDINAVIAN SEA.[5] The

vessel, which was on a daily 11 hour cruise to no-where[1] out of Port Canaveral, Florida, carried 744 passengers and 202 crewmembers. At the time of the fire, the vessel had just gotten under way after being anchored about 7 miles off the coast of Florida, near Port Canaveral. It proceeded to its berth while the vessel's firefighting team fought the fire. The passengers were disembarked, and the Coast Guard and local firefighters boarded the vessel to fight the fire. The fire was finally extinguished 2 days later on March 11, 1984. There were no injuries or loss of life. However, the vessel was declared a total loss, being valued at $16 million.

The Cape Canaveral Volunteer Fire Department was under contract to the Port Authority to provide fire protection to the port area, including the Cruise Terminal. As a result of its investigation of this accident, the Safety Board determined that the volunteer fire department had not been trained in fighting ship board fires. Consequently, vessel stability became an issue as water was pumped onto the vessel, and ventilation of the hot area occurred too early and the fire flared up after being extinguished. In addition, the Safety Board determined that there was no contigency planning and the fire fighters were without any information regarding the operation and location of emergency equipment on board the vessel.

In the same year (August 20, 1984), the Safety Board investigated a fire on board the Bahamian registered passenger ship M/V SCANDINAVIAN SUN that operated out of the port of Miami, Florida.[6] The fire erupted in the auxiliary machinery (generator) room and spread to adjoining spaces while the vessel was docked at the Port of Miami. It had just completed a 14-hour round trip cruise to Freeport, Bahamas with 530 passengers and 202 crewmembers. One passenger and one crew member died as a result of the fire. Damage and repair costs were estimated to be $2.3 million.

The Safety Board determined that fire doors had to be closed manually and the ventilation system had to be shut down manually because the fire protection system had been left on manual instead of automatic even though the pilot house was not occuppied at the time the fire started. The investigation showed that CO_2 was released into the wrong room and thus was ineffective in extinguishing the fire because the system was poorly labeled and the crew inadequately trained.

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[1]These cruises were 1-day excursions beyond the territorial waters of the United States (beyond 3-mile limit) so that passengers could participate in legal gambling operations on board the vessel.

Fire on board the Bahamian registered SCANDINAVIAN STAR that occurred on March 15, 1988, started in the engine room.[4] At the time of the fire the ship was about 50 nmi northeast of Cancun, Mexico, in route from Cozumel, Mexico, to St. Petersburg, Florida, with 439 passengers and 268 crewmembers on board. The fire caused loss of power and the passengers were evacuated with other vessels. The loss of the main generator and emergency generator electrical power and the malfunction of the ship's fixed CO_2 firefighting system hindered efforts to fight the fire. Language barriers between crewmembers hampered firefighting and evacuation of the passengers. Four individuals were injured in this accident. Damage and repair costs were estimated at $3.5 million.

As a result of this specific fire on the SCANDINAVIAN STAR, the Safety Board issued 26 safety recommendations to correct safety deficiencies in firefighting equipment, firefighting training, emergency plans, and crew communications. After this accident, the SCANDINAVIAN STAR was sold and in March 1990 went into ferry service in the North Sea. At that time the Safety Board was aware that the safety recommendations regarding fire safety had not been implemented. Perhaps the tragic loss of life could have been prevented or the numbers reduced had these earlier recommendations been implemented.

The Safety Board issued a series of recommendations based on investigation of passenger vessel fires. These recommendations related to vessel maintenance, fire protection, crew qualifications, and other fire safety issues aboard foreign cruise ships. In May of 1992, the Coast Guard and the IMO's Maritime Safety Committee acted to establish and enforce additonal fire safety requirements that include adopting SOLAS amendments requiring smoke detectors, automatic sprinkler systems, and other fire safety requirements. These amendments would apply not only to new ships but also to existing ships.

FIRE HAZARDS IN HIGHWAY TRANSPORTATION

One of the most tragic bus fires occurred at approximately 10:55 p. m. on May 14, 1988, near Carrollton, Kentucky.[7] The bus was owned and operated by a church group. It was occupied by 4 adults (one was the driver) and 63 children ranging in age from 10 to 18. The group was returning from a church outing. The bus was struck on the right front by a pickup truck traveling the wrong direction on a divided four lane highway. The pickup truck underrode the front of the bus and was driven backwards by the bus. Twenty six passengers and the bus driver were fatally injured in the accident. Thirty six additional passengers were injured, 7 of whom were critically injuried. Cause of all fatalities was listed as "smoke

inhalation;" none of the fatalities was caused by impact injuries.

A witness to the accident stated that immediately on impact the front of the bus burst into flames. The postaccident investigation showed that the gasoline tank, located next to the main entrance and exit to the bus, was pushed rear-ward about 28 inches and was punctured. As a result of the impact, a 2-inch-wide separation in the floor between the first and second rows of seats extended the width of the interior directly above the displaced fuel tank. Since the fire started at the front of the bus near the main egress point, this exit was unuseable. The rear exit was partially block by the rear seats extending into the exit area, which restricted passenger egress. Had this exit been completely open, more passengers could have exited.

The pickup truck driver survived the accident with relatively minor injuries. About 1.5 hours after the accident, blood was taken from the pickup truck driver for toxicological testing. His blood alcohol concentration (BAC) at that time was 0.26 percent. Calculations indicate that his BAC at the time of the accident was probably about 0.28 percent.

The investigation of this accident exemplifies what occurs in many accidents that the Safety Board investigates; that is, many factors come together that lead to an accident that results in multiple deaths. In this accident these factors include: an individual who has a serious drug dependence problem that is known by family, friends, and law enforcement agencies; a bus that has an unprotected gasoline tank located next to the main egress point; and an emergency exit on the bus that is partially blocked by seats that restrict egress through this exit.

Based on the Safety Board's investigation of this accident, the Safety Board recommended that the 50 States phase out the use of school buses manufactured before April 1977 and the States should convene task forces within their states to review their DUI (driving-under-the-influence) legislation and implement administrative license revocation programs as well as enhance public awareness programs. In addition, the Safety Board suggested that the National Highway Traffic Safety Adminstration (NHTSA) revise Federal Motor Vehicle Safety Standard 301 to provide additional protection for school buses in severe crashes based on an evaluation of the merits of relocating fuel tanks. The Safety Board also directed recommendations to NHTSA regarding emergency egress and the development of criteria to reduce the rate of fire spread of materials used in buses.

This accident also illustrates that there are other technological solutions or options

to reduce the potential of fires in accidents. Obviously, it would be effective to use only diesel powered engines which use a lower volatile fuel, to place the fuel tank between the frame rails or install a protective cage around the tank (a cage was an option on this bus), and to increase the size or number of emergency exits. However, if more emergency exits are required, then the system must be engineered to prevent the inadvertent opening of such exits in a different accident sequence which could result in ejection of passengers. One needs to be certain that the next technological fix does not create the next technological problem that only becomes known from an investigation of the next accident.

FIRE HAZARDS IN AVIATION

Fires aboard aircraft have been categorized into 3 general areas, (1) ramp fires (includes taxiing fires), (2) inflight, and (3) post-crash.[8] Frequently, post-crash fires involve fuel spills and when the fuel is ignited it creates unique fire protection problems because of the intensity of the fire which usually gets into the cabin area in a very short time. Perhaps one of the most difficult problems is the inflight fire because getting the aircraft on the ground quickly becomes necessary. Fortunately, this has become a rare occurrence. All fires in commercial aviation create a serious threat to passengers, crew, and people on the ground.

In 1976, the Safety Board initiated a special study on the incidence of aircraft accidents accompanied by fire.[9] This study analyzed the statistical data on aircraft fires during the period 1965 to 1974 and estimated that 15 percent of all fatalities in U.S. air carrier accidents were attributed to the effects of fire. The Federal Aviation Administration (FAA) responded to the fire hazard in commercial aviation by an ongoing fire research program to assess the fire hazard of aircraft interior materials through large scale fire testing. In 1978, the Federal Aviation Administration established the Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee to make recommendations on survivability in postcrash fires. One of the recommendations from the SAFER committee was the fire blocking concept. Based on these recommendations, the FAA carried out a research and fire testing program. This work resulted in increasing the fire hardness of interior furnishings through the use of new more stringent fire standards and performance criteria and the use of fire blocking materials for seat cushions. According to FAA estimates, the use of fire blocking material could increase the survivable escape time about 50 percent.[8] However, the 50 % increase in escape time is from about 145 seconds to about 210 seconds depending on the fire scenario; even with this increase, the amount of time to escape remains short.

The following discussion illustrates recent commercial aviation accidents that involved fires. In almost all of these accidents, fires developed rapidly and destroyed the aircraft. When fire started outside the aircraft, the fire rapidly burned through the fuselage and spread into the cabin interior and became life threatening very rapidly. In some cases the passengers were able to escape; however, in several cases, a substantial number of passengers and crewmembers were unable to exit the aircraft.

The most recent inflight fire occurred in a South African Airways Boeing 747 Combi over the Indian Ocean on November 28, 1987.[10] The aircraft carried five flight crewmembers, 14 cabin crewmembers, and 140 passengers, all of whom perished in the accident. A debris field and the cockpit voice recorder was located on the ocean floor at a depth of about 15,000 feet. The CVR and a limited amount of debris from the aircraft were recovered. Extensive under water photographic records were made of the debris field. The CVR provided little information on the nature of the fire. Only about 1.5 minutes of the recording contained conversation related to the inflight emergency, the rest being cut off presumably as a result of fire damage to the audio input wiring to the CVR. A master fire alarm was identified and a voice identified the fire as being in the main cargo deck area. Communications with Mauritius Approach Control was recorded and provided the following information. The captain reported a smoke problem to the controller about 46 minutes short of Mauritius. About 3 minutes later, he reported the loss of a lot of electronics and then "we haven't got anything on the aircraft now." About 13 minutes later the aircraft crashed into the Indian Ocean. Only small amounts of wreckage and eight bodies were recovered. Extensive video recordings of the underwater wreckage showed that the fire appears to have started in a pallet immediately behind the bulkhead that separates the cargo section from the passenger compartment. Toxicology on recovered victims showed lethal levels of carboxyhemoglobin saturation.

As a result of this investigation, the Safety Board recommended that FAA require that; (1) all cargo carried in Class B cargo compartments of US registered aircraft be carried in fire resistant containers, (2) research be conducted to establish the fire detection and suppression methods necessary to protect transport aircraft from catastrophic fires, and (3) fire resistant requirements be established for the ceiling and sidewall liners in Class B cargo compartments that equal or exceed the requirements for Class C and D cargo compartments.

The FAA responded to this accident and the Safety Board recommendations by issuing an airworthiness directive (AD) that required; equipment changes, design

modifications to maximize cargo fire detection and control, periodic inspection of cargo area, flight crew fire fighter training, breathing and communication equipment, and fire extinguishing materials.

An inflight fire occurred in an Air Canada DC-9 on June 2, 1983.[11] The aircraft was diverted to the Cincinnati International Airport in Covington, Kentucky. The flight left Dallas with 5 crewmembers and 41 passengers. Smoke was discovered in the left aft lavatory while the flight was at 33,000 feet. The aircraft was landed safely, however, 23 passengers died in the ensuing fire that destroyed the aircraft. The investigation of this accident showed evidence of electrical arcing between the generators electrical leads and two lightening holes in the floor beam. This aircraft had 76 write-ups concerning the two engine-driven generators and the auxiliary power unit (APU) generator that were not resolved prior to the accident flight. In 1979, the aircraft experienced an inflight failure of the aft pressure bulkhead that resulted in extensive damage to the aircraft including buckling of the floor forward of the left aft lavatory where the generator electrical leads run under the cabin floor.

On August 22, 1985, a Boeing 737 caught fire during the take-off roll in Manchester, England.[12] The aircraft was carrying 131 passengers and 6 crewmembers. During the take-off roll, the left engine experienced an uncontained engine failure at 125 knots. An engine part struck and penetrated an access panel to the right wing fuel cell, releasing fuel. A fire started immediately and the fire, which was unknown to the cockpit crew, trailed behind the left engine. Take-off was aborted because the crew assumed that a tire had blown. Fire trailed the aircraft as it taxied to a stop. The ensuing ground pool fire spread rapidly into the cabin, destroyed the aircraft, and 55 people lost their lives including two cabin attendants. Unfortunately, in this accident the crew parked the aircraft with the prevailing winds blowing the fire into the fuselage. This fire and its consequences continues to feed the ongoing debate about providing smoke masks/hoods for use by aircraft passengers during emergency egress from a burning aircraft.

On March 22, 1984, a Boeing 737 caught fire during the take-off roll in Calgary, Alberta. The aircraft was carrying 114 passengers with a crew of 5.[13] During the take-off roll, the engine experienced an uncontained left engine failure (failure of compressor disk) at about 70 knots, which the crew heard as a loud bang accompanied by a veer to the left. A fire started immediately; however, the crew did not order an evacuation for almost 2 minutes after the first evidence that precipitated the rejected take-off. Almost a full minute was lost while the cockpit crew diagnosed the problem even though passengers were aware of the fire within 10 seconds of the initiating occurrence. Everyone survived this fire; however, 4

persons were seriously injured during the evacuation. It was estimated that it took about 2 to 3 minutes to evacuate the aircraft.

The FAA and the international aviation community has had an on-going effort to increase fire safety in commerical aviation. In the United States, new flammability regulations covering transport category airplanes (14 CFR Parts 25, 29, and 121) were published on seat cushion materials (fire blocking) on October 26, 1984.[14] Compliance was required after November 26, 1987 on aircraft manufactured after January 1, 1958. On August 25, 1988, the FAA published new refined fire test procedures and apparatus and a new requirement for smoke emission for transport category airplanes operating under 14 CFR Parts 25 and 121.[15] The new refined fire test procedure used to qualify interior materials for aircraft is the Ohio State University (OSU) rate-of-heat-release apparatus (ASTM-E-906).

Fire blocking for seat cushions and new fire test method with standards to require more fire resistant materials for cabin interiors have increased fire safety. However, more can be done to reduce the fire risk in aviation.

CONCLUSIONS

Accident investigations carried out by the National Transportation Safety Board have highlighted a variety of fire hazards in the transportation environment. While improvements have been realized as a result of these investigations, more efforts are needed to address the factors involving fire in transportation. In may instances, fire is a result of collision dynamics and may or may not involve the ignition of large quantities of liquid fuels. However, in some cases, fire is the initiating factor that leads to an accident. Presently, an interagency government group is being assembled to exchange information on heat- and fire-resistant composite materials. Hopefully, this interaction will increase fire safety in all modes of transportation and will continue to reduce human injury and fatalities.

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